DOCUMENT RESUME

ED 379 421 CE 068 101

TITLE	Trench Protection and Principles of Pipe Laying. Instructor Manual. Trainee Manual.
INSTITUTION	Laborers-AGC Education and Training Fund, Pomfret Center, CT.
PUB DATE	Jan 94
NOTE	305p.; For related documents, see CE 068 095-096 and CE 068 098-102. Photographs may not film with adequate clarity.
AVAILABLE FROM	Laborers-AGC Education and Training Fund, 37 Deerfield Road, P.O. Box 37, Pomfret Center, CT 06259 ($12).
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052) -- Guides - Classroom Use - Instructional Materials (For Learner) (051)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Adult Education; *Building Trades; *Construction (Process); Construction Industry; Instructional Materials; *Plumbing; Postsecondary Education; *Safety; Safety Education; Teaching Guides
IDENTIFIERS	*Excavations; *Pipelines; Pipe Workers

ABSTRACT

This packet contains the instructor and trainee manuals for a course dealing with trench protection and principles of pipe laying. Part 1 is the instructor guide for an 80-hour course--12 classroom hours and 68 hours of hands-on exercises. Contents are as follows: a course outline; course schedule; equipment list; material and equipment checklist; audiovisual checklist; site design information; equipment, tools, and materials list by section; checklist of hands-on exercises; and instructor's reference notes for classroom discussion. The course is designed in four sections. Sections I-III cover trenching and excavation safety, pressure pipe laying techniques, and utility line and grade. Each section begins with a 4-hour classroom session followed by three hands-on exercises of 4 hours each. Section IV (gravity flow piping systems) allows the trainee to practice or demonstrate skills acquired during the first portion of the course by actually installing a gravity flow pipe, a pressure water pipe, a storm drain pipe, and constructing a manhole and/or inverts. These exercises are designed for 10 hours each and the trainees rotate through each task. Part 2 of the manual contains assignment sheets for all sections. Part 3 is the trainee manual. Each section contains objectives, terms and definitions, informative material, and assignments sheets. Appendixes include a glossary of terms and abbreviations and Occupational Safety and Health Administration construction standards for excavations. (YLB)

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Laborers-AGC Education and Training Fund

ED 379 421

Trench Protection and Principles of Pipe Laying

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Instructor Manual

TRAINEE

MANUAL

CE 068 101

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Trench Protection and Principles of Pipe Laying

INSTRUCTOR GUIDE

PIPE LAYING INSTRUCTORS GUIDE 1

PIPE LAYING ASSIGNMENT ANSWER SHEETS 2

PIPE LAYING TRAINEE MANUAL 3

GLOSSARY OF TERMS AND ABREVIATIONS 4

APPENDIX B AND C 5

About the Course

This course is designed in four sections. Section I, II, and III cover "Trenching and Excavation Safety," "Pressure Pipe Laying Techniques," and "Utility Line and Grade" respectively. These sections are designed to teach techniques and practices that will be demonstrated by the trainees during the hands-on portion of each section.

The curriculum is designed to take 80 hours. Even though it is not possible to teach all the information that an experienced pipe layer should know in this amount of time, it will teach the basics needed to start and survive on a pipe crew. Of the 80 hours, 12 hours are classroom and 68 hours are hands-on exercises.

Sections I, II, and III will begin with a 4-hour classroom session, followed by three hands-on exercises of 4 hours each. To rotate a trainee through the first three sections will take 48 hours.

Section IV allows the trainee to practice or demonstrate skills acquired during the first portion of the course by actually installing a gravity flow pipe, a pressure water pipe, a storm drain pipe, and constructing a manhole and/or inverts. These exercises are designed for 10 hours each and the trainees should rotate through each tasks.

Assignment sheets have been included for all sections. It is recommended that the information needed to complete these assignment sheets be taught in the classroom session and the assignments sheets be utilized as homework.

To assist the instructor, specific task job sheets have been prepared for each trainee. For safety reasons and to save time during each exercise, these job sheets should be carefully reviewed with the trainees prior to beginning each exercise. These job sheets will also help to establish what tasks a trainee competency profile could be based on.

Competency profiles have been included and should be maintained on all trainees for the following reasons; they will allow the instructor(s) to systematically evaluate the effectiveness of the program and field exercises. They will also serve to boost the confidence level of the trainees completing the course. Most importantly however, the trainee can use it to determine exactly what tasks are required during the course and what areas he or she should continue to practice after the course.

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Course Outline

SECTION I: Trenching and Excavation Safety

A. Audio visual
1. OSHA slide tape presentation
2. Laborers-AGC video presentations:
"Site Safety Planning for Excavation Projects"
"4 Minutes to Survival"

B. Excavations
1. OSHA regulations regarding excavations
2. Angles of repose for various soil types
3. Weather factors that will affect soil conditions
4. Unsafe work practices that will affect soil conditions

C. Trenches
1. OSHA regulations regarding trenches
2. Trench box
3. Hydraulic bracing
4. Working with screw jacks
5. Working with timber bracing
6. Working with pipe sections in shored conditions

Section II: Pressure Pipe Laying Techniques

A. Audio visual
1. Laborers-AGC video presentation:
"General Techniques of Pipe Laying"

B. Layout and preparation
1. Tool identification
2. Pipe parts identification
3. Plumbing code requirements
4. Crew responsibilities
5. Repair methods

C. Potable Water Distribution Systems
1. General overview and principles
2. Accuracy requirements
3. Pipe types
4. Installation techniques
5. Design and installation of services
6. Repair and tie-in methods
7. Common test specifications and procedures

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Course Outline (continued)

Section III: Utility Line and Grade

A. Audio visual
   1. Laborers-AGC video presentation:
      "Basic Principles used in the Transfer of Grade Points"

B. The decimal system
   1. Description of the decimal system
   2. Converting between U. S. Standard and the decimal system

C. Common staking systems
   1. Staking systems and information
   2. Stationing system
   3. Gradient expressions
   4. Calculating gradients

D. Line and Grade Equipment
   1. Holding and reading a grade rod
   2. Set-up and working with batter boards and string line
   3. Set-up and working with a transit and level
   4. Set-up and working with a pipe laser

Section IV: Gravity Flow Piping Systems

A. Audio visual
   1. Laborers-AGC video presentation:
      "On Solid Ground: A Plan for Safe Excavation and Trenching"
      "Spectra-Physics: Dial Grade Basic Training"

B. Sanitary Sewer Systems
   1. General overview and principles
   2. Accuracy requirements
   3. Pipe types
   4. Installation techniques
   5. Installation techniques of laterals
   6. Repair and tie-in methods
   7. Manhole uses and designs
   8. Common test specifications and procedures

C. Storm Drain Systems
   1. General overview and principles
   2. Accuracy requirements
   3. Pipe types
   4. Installation techniques
   5. Design and installation techniques for sub drains
   6. Manhole/catch basin uses and design

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Course Schedule

Section I: 16 hours total, 6 trainees per group

Classroom session - 4 hours:

8:00 to 9:00	OSHA slide tape presentation and discussion
9:00 to 9:45	Laborers-AGC section video, discussion of terminology and techniques presented in the film.
9:45 to 10:00	Discussion of specific local practices in shoring, trenching, or excavation.
10:00 to 12:00	Review of section I job sheets and hands-on exercises.

Hands-on exercises - 12 hours (total)

12:30 to 4:30 Hands-on exercises constructing:

1. Hydraulic shoring, install pipe
2. Skeleton shoring with screw jacks, install pipe
3. Close sheet shoring, install pipe

Section II: 16 hours total, 6 trainees per group

Classroom session - 4 hours:

8:00 to 9:00	Laborers-AGC section video, discussion of terminology and techniques presented in the film.
9:00 to 11:00	Lecture and assignment sheets.
11:00 to 12:00	Review of section II job sheets and hands-on exercises.

Hands-on exercises - 12 hours (2 trainees per exercise, rotate every 4 hours):

12:30 to 4:30 Hands-on exercises:

1. Batter board/string line set up
2. Level and transit set up
3. Pipe laser set up

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Course Schedule (continued)

Section III: 16 hours total, 6 trainees per group

Classroom session - 4 hours:

8:00 to 9:00	Laborers-AGC section video, discussion of terminology and techniques presented in the film.
9:00 to 10:00	Lecture on local plumbing code
10:00 to 11:00	Pipe parts and tool identification
11:00 to 12:00	Review of section III job sheets and hands-on exercises.

Hands-on exercises - 12 hours (2 trainees per exercise, rotate every 4 hours):

12:30 to 4:30 Hands-on exercises:

1. Cut off saw use and maintenance
2. Sewer and water service assembly
3. Mechanical and repair coupling assembly

Section IV: Gravity Flow Installation, 10 hours total, 6 trainees rotated through each task

Day seven:	8:00 to 4:30	Install gravity flow pipe.
Day eight:	8:00 to 10:00	Complete group 1 installation, pressure test, clean up and remove pipe.
Day eight:	10:00 to 4:30	Install gravity flow pipe.
Day nine:	8:00 to 12:00	Complete group 2 installation, pressure test, clean up and remove pipe.
Day nine:	12:30 to 4:30	Install gravity flow pipe.
Day ten:	8:00 to 2:30	Complete group 3 installation, pressure test, clean up and remove pipe.

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Course Schedule (continued)

Section IVa: Manhole/invert construction, sanitary service installation, utility adjustment, 10 hours, 6 trainees rotated through each task

Day seven:	8:00 to 4:30	Group 1 pour inverts, install lateral, adjust utilities.
Day eight:	8:00 to 10:00	Complete exercises for group 1 and clean up.
Day eight:	10:00 to 4:30	Group 2 pour inverts, install lateral, adjust utilities.
Day nine:	8:00 to 12:00	Complete exercises for group 2 and clean up.
Day nine:	8:00 to 12:00	Group 3 pour inverts, install lateral, adjust utilities.
Day ten:	8:00 to 2:30	Complete exercises for group 3 and clean up.

Section IVb: Install pressure pipe, 10 hours, 6 trainees rotated through each task

Day seven:	8:00 to 4:30	Group 1 pipe installation
Day eight:	8:00 to 10:00	Complete group 1 installation, pressure test, clean up and remove pipe
Day eight:	10:00 to 4:30	Group 2 pipe installation
Day nine:	8:00 to 12:00	Complete group 1 installation, pressure test, clean up and remove pipe
Day nine:	8:00 to 12:00	Group 3 pipe installation
Day ten:	8:00 to 2:30	Complete group 1 installation, pressure test, clean up and remove pipe

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PIPE LAYING 80-HOUR SCHEDULE
EIGHT 10-HOUR DAYS

Day 1

Pipe I - Section I
4 hours - Classroom
1 hour - Hands-on
Hydraulic shoring and screw jacks

Pipe I - Section II
3 hours - Classroom
Tool and parts ID in shop

1 hour - Hands-on
Set-up for Section II hands-on

Day 2

Pipe I - Section II
8 hours - Hands-on

Pipe II - Section I
2 hours - Classroom

Day 3

Pipe II - Section I
5 hours - Classroom
5 hours - Hands-on

Day 4

Pipe II - Section I
7 hours - Hands-on

Haz Comm
3 hours - Classroom

Day 5 (Machine starts here, approx. 35 hours)

Pipe I - Section I
8 hours - Hands-on
Split crew, 1/2 shoring, 1/2 transits and lasers

Pipe I - Section II
2 hours - Hands-on
Set up trench box

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Day 6

Pipe I - Section II
8 hours - Hands-on
Split crew, 1/2 on pressure pipe, 1/2 on transits and lasers

Pipe II - Section II
2 hours - Classroom

Day 7

Pipe II - Section II
2 hours - Classroom

8 hours - hands-on
Split crew, 1/2 sanitary installation, 1/2 laterals, pipe repair, inverts

Day 8

Pipe II - Section II
8 hours - Hands-on
Split crew, 1/2 storm installation, 1/2 transits and lasers, math, etc.

2 hours - Cleanup and certificates

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CST 40 Hour Basic Pipe Course - Equipment, Tools, and Materials

Shoring Materials:

Timbers	-	12 ea.	6"x8"x 12'
Sheeting	-	32 ea.	2"x 10"x 16'
Cleats		-	10 ea. 2"x8"x16'
Plywood	-	8 ea.	3/4" CDX 4'x8'
Nails	-	50#	16d duplex

Tools:

Bars	-	2 ea.	
Pipe Slings	-	2 ea.	1/2" choker w/hook
Shovels	-	4 ea.	long handle round
"	-	4 ea.	short handle round
"	-	2 ea.	long handle square
"	-	2 ea.	short handle square
Hammers	-	6 ea.	20 oz. framing
"	-	2 ea.	8 lb. sledge
"	-	2 ea.	ballpeen
Wrenches	-	2 ea.	long handle 1/2" drive ratchets
"	-	2 ea.	combination 1 1/4" open/box
"	-	1 ea.	15" adjustable (Crescent)
Sockets	-	2 ea.	1/2" to 1 1/2" (1/2" drive)
Saber Saw	-	1 ea.	w/key hole bits (for sewer services)
Saw Blades	-	1 box	for metal (abrasive 3/16 x 12")
" "		-	1 box for concrete (abrasive 3/16 x 12")
Levels		-	2 ea. 4 foot
"	-	2 ea.	torpedo
Cheater pipes		-	2 ea. 1 1/2" x 18"
Tapping Bits		-	2 ea. 3/4" for DI pipe
Flaring Tools		-	2 ea. For 3/4" copper-impact type

Equipment:

Air Compressor	1 ea.	175 cfm.
65 # Breaker		1 ea. w/100' hose and sheet driver bit
Hydraulic uprights		8 ea. 7 ft.
Screw Jacks		8 ea. w/ 3' pipes
Transit & Level	1 ea.	w/ grade rod
Tapping Machine	1 ea.	Mueller B-100 (for 3/4-1")
Cutoff Saws		2 ea. for 12" blade size
Excavator	1 ea.	Track Hoe w/360° swing
Compaction Equip.		1 ea. vibratory plate
" "		1 ea. rammer
Test Pump	1 ea.	
Hazardous Atmosphere Sensing Equip.		1 ea.
Polyethylene Fusing Machine		1 ea.

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Piping Materials and Fittings:

Pipe	-	198 lf.	6" Ductile Iron
"	-	40 lf.	4" polyethylene
Hydrant Assb.		1 ea.	6" single pumper (and wrench)
6" Tees	-	2 ea.	w/flange,gasket,bolts etc.
6" Gate Valves		2 ea.	w/flange,gasket,bolts, boxes. and wrench etc.
6" 22 1/2° Bend		1 ea.	w/flange,gasket,bolts etc.
6" Cap		1 ea.	w/flange,gasket,bolts etc.
6" MJ Plug	-	1 ea.	
6" MJ Tapped Plug		1 ea.	w/2" x 3/4" reducer
Eye Bolts		8 ea.	w/nuts (for tie rod assmb.)
All Thread		30 lf.	3/4" w/16 flat washers and nuts
Extra Tee Bolts		12 ea.	
Precast Thrust Blocks		4 ea.	6" x 2' x 2' (pour on site)

Repair Couplings:

Smith Blair	-	2 ea.	6"
Wrap Around	-	1 ea.	6"

Service Assemblies:

Corporation Stops	4 ea.	3/4"
Curb Stops	4 ea.	3/4"
Type K copper	1 ea.	100' roll

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MATERIAL AND EQUIPMENT CHECKLIST

Shoring Hands-on

Safety equipment - general

1 ea. - hard hat
1 ea. - goggles
1 ea. - ear plugs
1 ea. - safety boots
1 ea. - leather gloves
1 ea. - instructors and support person two-way radios with carrying case

Safety equipment - special

1 - class A ear muffs (chain saw)
1 - wire mesh shield (chain saw)
1 - ballistic nylon chaps (chain saw)
1 - ballistic nylon gloves/boots (chain saw)
1 - GFCI (ground fault circuit interrupter)
12 - barricade systems
1 - 20' extension ladder
1 - face shield with bullard bracket

Equipment

excavator with 36" maximum bucket
backhoe with forks
chainsaw
skill saw
generator
water pump
air compressor
MSA 361 combustible gas indicator
MSA 361 calibration kit
flow control (1.5 liters per minute)
.75% Pentane/15% Oxygen gas cylinder
40 PPM Hydrogen Sulfide gas cylinder
10 PPM Hydrogen Sulfide gas cylinder
adapter hose
instruction Manual, model 360/361

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Driving sheeting

2 - 90# pavement breaker
2 - sheet driving attachment
4 - 20' air hoses
2 - whip lines
2 - in line oilers
1 - rock drill oil
6 - air hose gaskets
6 - whipcheks
6 - safety clips or rebar wire

Timber tight sheet shoring

80 - 2" x 12" x 8' sheeting with 1-1/2" x 6" cleats
8 - 6" x 8" x 12' walers with 1-1/2" x 6" cleats
20 - 6" x 8" x 48" crossbraces with 1-1/2" x 6" cleats
20 - 6" x 8" x 36" uprights with 1-1/2" x 6" cleats
10 - 6" x 8" x 12" blocks

Hydraulic shoring

6 - 7' hydraulic shoring
2 - hydraulic hand pumps with connection lines
10 - 4' x 8' x 3/4" CDX plywood
1 - bleeder (release bar)
1 - hydraulic oil

Skeleton shoring

16 - screw jacks
8 - 2" x 10" x 8' sheeting

Scaffold

4 - 5' box frames
4 - cross braces
4 - mud sills
4 - brackets (outrigger)
14 - scaffold planks with cleats
8 - screw jacks

Hoisting and rigging

2 - 3" x 10' nylon slings
2 - 3" x 8' nylon slings
2 - 2" x 8' nylon slings
2 - 1/2" shackles
1 - hoisting chain with hooks

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Water pump

40' - discharge hose
15' - suction hose

Miscellaneous tools

6 - crowbars
1 ea. - tape measures
2 - 4' levels
1 ea. - claw hammers
1 ea. - hammer holder
1 - sledge hammer
8 - square mouth shovel
8 - round mouth shovel
2 - track shovel (sharp shovel)
1 - roll flagging
1 - linesman pliers for rebar wire on air hoses
1 - 3/4" x 10" standard screwdriver (line oilers)
1 - small standard screwdriver (MSA 361)

Other miscellaneous equipment

4 - 20' x 10 gauge electrical cord
3 - 20' x 12 gauge electrical cord
1 - 20 x 14 gauge electrical cord
1 - box 3-1/2" duplex nails 16d
1 - gas container with mixed gas
1 - rubber pail
1 - canvas pail

Pipe Fusion Hands-On

2 - 75' electrical cord
1 - generator
1 - polyethylene pipe
1 - GFCI (ground fault circuit interrupter)
1 - hacksaw
1 - heating paddle
1 - paddle stand with holder
1 - cutting machine
1 - pipe fusion cart
8 - masonry block/wooden block
1 - 4' level
1 - gas for generator

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Cut-off Saw Hands-on Exercise

2 - quickcut saws
6 - cut off blades
2 - bullard bracket with face shield
2 - 20' ductile iron pipe
1 - socket set
1 - Bosch R-10 spark plug

Live Mueller Tap

1 - ductile iron pipe with end caps
1 - thrust block
1 - steel choker
1 - backhoe
1 - Mueller machine with accessories
2 - 18" pipe wrench
6 - corporation stops
2 - 10' copper tubing (3/4")
2 - flaring tool (3/4")
2 - 20 oz. ball peen hammer
2 - pipe cutter
1 - test pump
2 - 12" pipe wrench
2 - 100' reinforced water hose (3/4" male NPT to 3/4" female brass)
1 - 3/4" ball valve (female - female)
1 - 3/4" bleed off valve (outlet)
1 - 3/4" connector (female - male)
2 - 12" adjustable wrench
1 - fuel container
2 - round mouth shovel

Mueller Tapping Machine Demonstration

1 - tapping machine with kit
1 - corporation stop
1 - teflon tape
1 - cutting grease (full can)
1 - tapping drill bit
2 - 18" pipe wrench

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PVC Saddle Connection

1 - magic marker
1 - GFCI
1 - 100' extension cord (12 gauge)
1 - PVC pipe (10')
3 - PVC saddle "y"
6 - saddle clamp
3 - 1/2" x 8" screwdriver
3 - round mouth shovels
1 - reciprocating saw
1 - cut off saw (Quickie saw)
1 - jigsaw/PVC blades
2 - course blades

Ductile Iron Pipe Repair

2 - repair clamps
1 - 4' level
2 - wrench (1-1/16")
1 - magic marker
2 - tape measure
2 - ratchet (1/2")
2 - deep sockets (1-1/16")
2 - round mouth shovels

Hydrant Assembly

1 - hydrant
2 - 4' pup
4 - regular tee bolt with nuts
4- valve tee bolts with nuts
1- gate valve (match hydrant size)
2 - eye bolts with nuts
1 - WD40
1 - wire brush
3 - ratchet (1/2" drive) with 1-1/4" deep socket
1 - air impact (1/2" drive) with 1-1/4" deep impact socket
1 - o-ring lock pin for impact
1 - air compressor
1 - air hose (25')
4 - whipchek
1 - in-line oiler
1 - adapter (chicago to quick couple fitting)
1 - torque wrench with 1-1/4" socket

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Pressure pipe installation

1 - existing line with "T" connection
2 - valves
1 - ductile iron pipe (20')
1 - "T" connection
1 - 4' pup
4 - ready rod (4')
70 - bolts with nuts
6 - eye bolts
1 - WD40
1 - backhoe
1 - excavator
6 - torpedo level
2 - 4' level
1 - load of sand
6 - round mouth shovel
1 - riser
1 - "T" bar key
1 - jumping jack tamper
1 - wire brush
2 - thrust block
1 ea. - box end speed ratchet (1-1/4" x 1-1/16)
3 - ratchet (1/2" drive) with 1-1/4" deep socket
1 - torque wrench
1 - air impact (1/2" drive) with 1-1/4" deep impact socket
1 - o-ring lock pin for impact
1 - adapter (chicago to quick couple)
1 - in-line oiler
4 - whipchek
1 - whip line
1 - 4 lb. sledge
1 - mixed fuel
1 - diesel/gas fuel
6 - rubber air line gaskets
1 - torque wrench with 1-1/4" socket

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AUDIO-VISUAL CHECKLIST

Laborers-AGC

Gravity Pipe Systems: Going With The Flow
Site Safety Planning for Excavation Projects
General Techniques of Pipe laying
Basic Principles Used in the Transfer of Grade Points
Understanding Material Safety Data Sheets
Understanding Labels
MSDS in Review
Hazcom Slide Presentation

Under Development

Back Injury Prevention (Health and Safety Fund)
Pressure Pipe Installation

Outside Vendors

We've Got it, Let's Use it - Ontario
On Solid Ground - AGC
4 Minutes to Survival - Neils Lindquist

Manufacturers

MSA 361
Mueller Tapping Machine
Spectra-Physics - Dialgrade Basic Training
McIllroy Pipe Fusion Machine
Nikon NE-20S

Possible Additions

Soil testing video
Permit required confined space video

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Site Design

Effective site design for a pipe laying course depends on many factors, such as available space, type of equipment, how many trainees, how many instructors, and many others. The design depicted here is only a guide for the exercises and variations of this design will be necessary according to local situations.

The most effective hands-on exercise is obviously "the real thing." Since we can not always provide that, the next best thing is to strive to make the exercises as real as possible. This means having the equipment available to actually install or practice the exercises shown below. Remember that safety is the most important factor in any hands-on exercise. Keep safety constantly in mind.

Illustration 1 depicts a possible layout for section I, II, and III exercises.

Section I: Shoring

Starting at a buried manhole and cone section, excavate for the shoring exercises. Install the shoring as the excavation continues, change bracing type according to time remaining in the group. Coordinate with the section II laser exercise for pipe installation through the shoring.

Section II: Batter boards

Set two rows of hubs with grades. Use the row closest to the shoring exercise for a two string set up to control line and grade for the shoring excavation and pipe. Use the second row to simulate a center line pipe string set up.

Transit/Level

The transit/level exercise uses offset referencing to locate only the bends or manhole locations of our hypothetical pipe. The tasks for the level/transit exercise are; to set up on center line and set back sights for each bend; and to determine the rod shots needed to place the pipe at the correct elevation at each bend.

Manhole Laser

The laser exercise should cover three set ups; in a pipe, in a manhole and above a pipe. Utilize the buried manhole and cone section for the manhole set up. Bury a small section of pipe in a shallow excavation to simulate a "in the pipe" set up and have offset hubs set for a "over pipe" set up.

Section III: General Techniques

A shop building (if available) can be utilized for the mechanicals and for the water service assembly exercises. The pipe saw exercises should be conducted outdoors, close to the rest of the exercises in section III.

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Site Design for Section I, II, and III Exercises

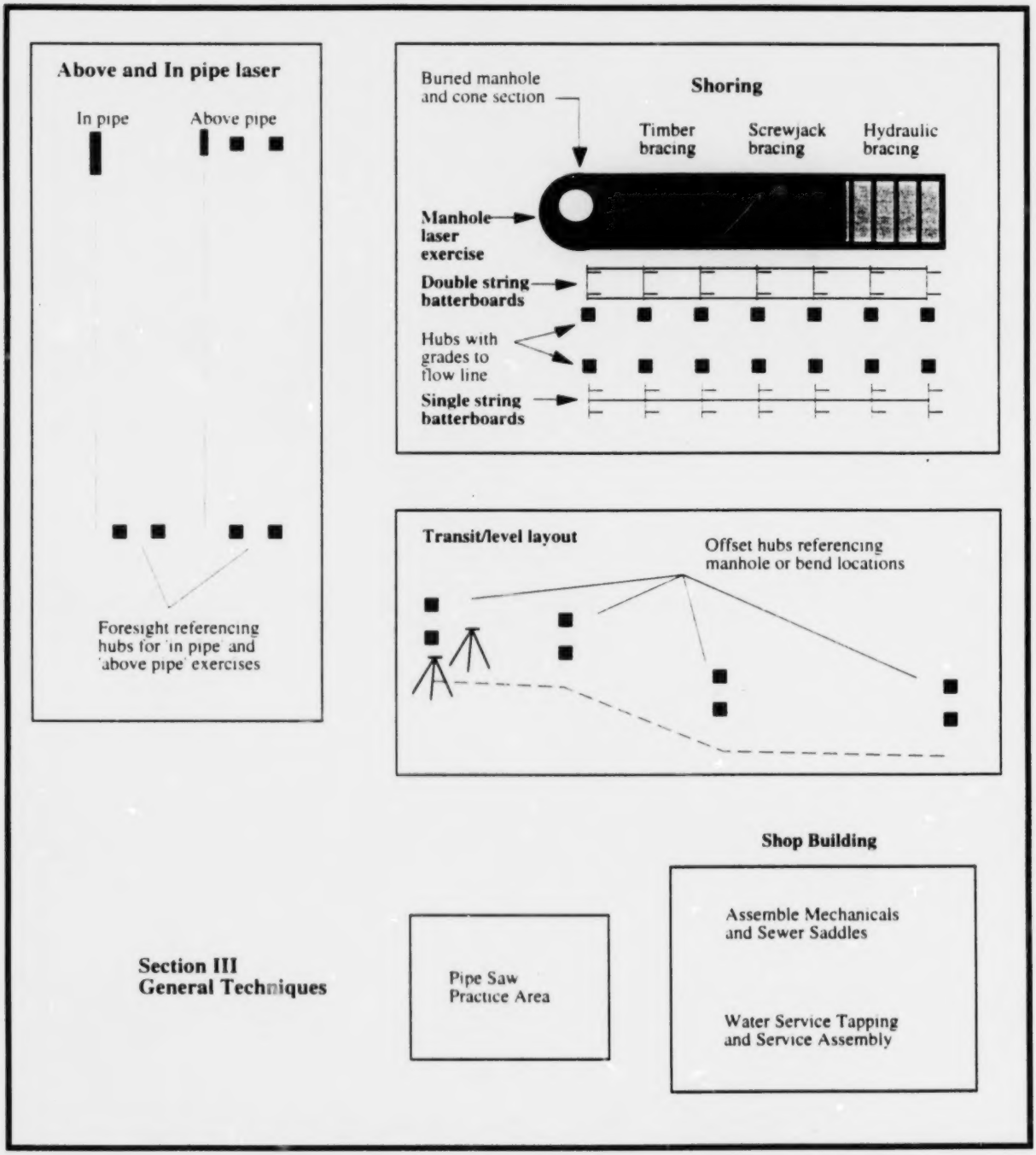

Illustration 1

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Site Design continued

The exercises for section IV should be designed to allow the trainees to practice or test the skills they developed in the previous sections in as realistic conditions as possible. This means actual gravity flow and pressure pipe installations. Utilize permanent installations wherever possible. If permanent installations are not needed or possible, then design the installations to be removed and re-installed by every trainee group. Slight alterations in length, alignment, or elevation should be used to force each group to simulate a new installation. In all exercises for sections IV, the trainees should be rotated through each task.

Illustration 2 depicts a possible training area for three exercises.

Section IV: Manhole/Inverts

Have the trainees pour and shape an invert. Using pozzolan or a pre-shape of wet sand and a mortar cap will reduce the time and waste from this exercise.

Lateral Install

Bury a small section of sanitary pipe in a shallow excavation and have the groups cut and install a saddle, then install the lateral line using a torpedo level for grade and different types of joining mechanisms (such as no-hub, then hubbed pipe, etc.).

Utility Adjustment

In an area that can simulate a final grade before paving or concrete, bury some concrete grade rings and a valve riser pipe, 12" to 18" deep. Have the trainee groups use a straight edge or string line to place the top castings to the final grade (top of paving). The tasks are; to determine the amount and size of grade rings required; and to install concrete shims and mortar to support the grade rings and top castings at the correct slope and elevation.

Section IVa: Gravity Flow

Begin excavating at the same manhole used in the section I and II exercises. Have the trainees install the laser in the manhole to provide line and grade. Install and back fill to top of pipe enough for each trainee to practice and/ordemonstrate each task to the instructors satisfaction. Plug and assemble the test mechanisms and either simulate or actually test the new section.

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Section IVb: Pressure Pipe

Begin excavating to expose a previously buried tee. When the tee is exposed, connect to it and begin installation and backfill to top of pipe. Have trainees maintain line and grade with either string line and batter boards or transit and level. Rotate trainees until each task has been demonstrated as mentioned above. Cap and assemble test mechanism and either simulate or actually test the new section.

CAUTION: Whenever air or water pressure is used to test a pipe section a hazard exists. Regardless of whether it is a low or high pressure test, be CERTAIN all caps, joints, and plugs are adequately installed and/or braced to prevent blow outs.

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Site Design for Section IV, IVa and IVb

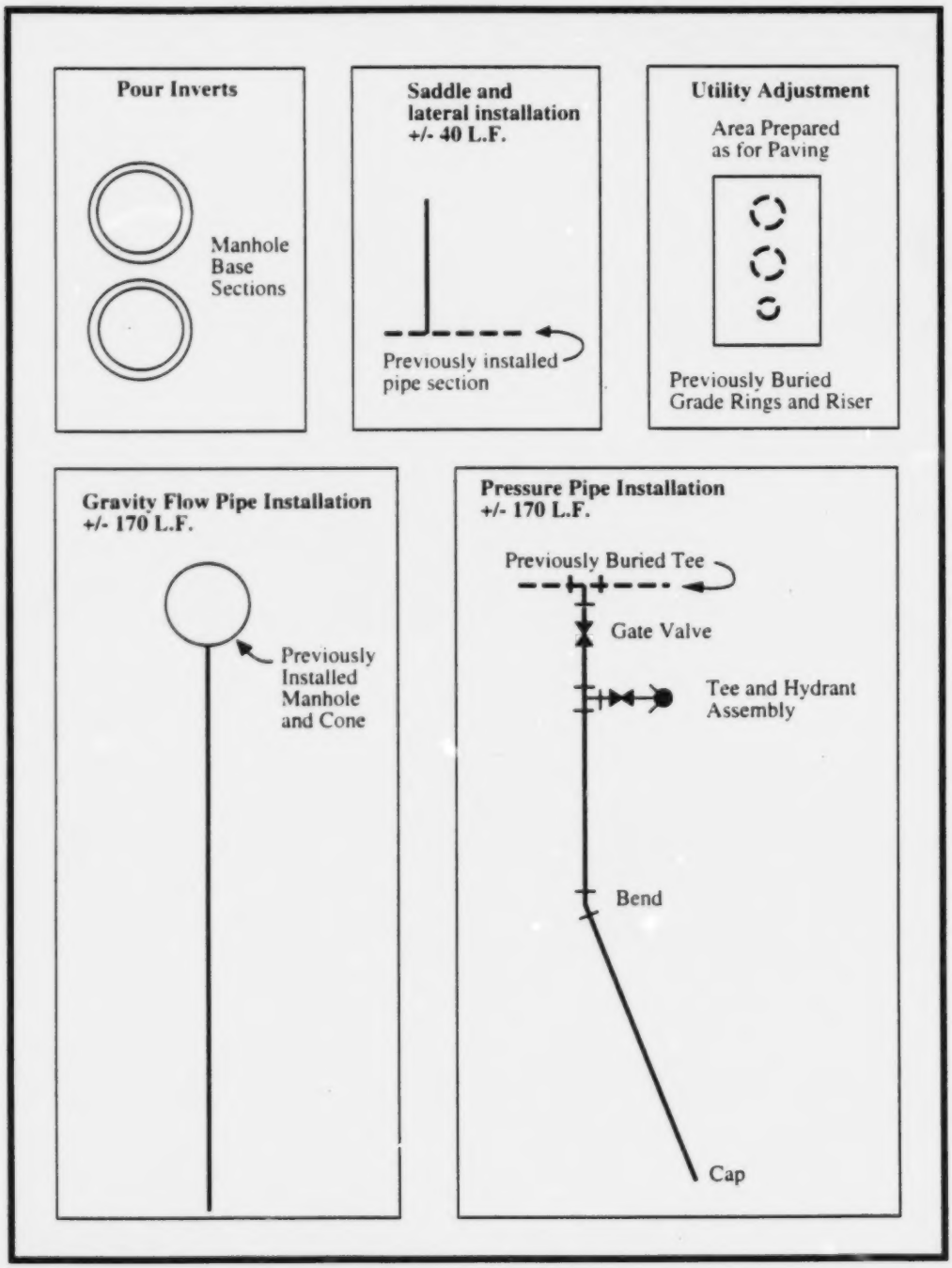

Illustration 2

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Equipment, Tools, and Materials

Section I: Class Room

video tape player and monitor
pencil and paper
trainee manuals
pencil sharpener
high liters

Section I: Hands-On

Materials:

shoring grade timber (size and quantity depends on conditions)
vertical sheeting lumber (size and quantity depends on conditions)
lumber for cleats (size depends on timbers / 8 cleats per crib)
16d duplex nails

Tools:

hard hats
safety glasses
gloves
ear plugs
shovels
hammers/nail aprons
4' level
25' measuring tapes
5' pry bars
crow bar
framing square
slings or chains
tie wire/whipcheks
65# pavement breaker
vertical sheet driver bit
1 1/2" cheater pipe
1 1/2" spreader pipes (1 spreader pipe per brace)
extension ladder/tie off rope

Equipment:

air compressor/100' hose (in-line "oiler or anti-freeze")
hydraulic bracing and pump/pressure release tool
screw jacks
base plates
excavator
gas/diesel fuel
transit/legs/plumb bob
level/legs/grade rod

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Equipment, Tools, and Materials (continued)

Section II: Class Room

video tape player and monitor
pencil and paper
pipe parts and appurtenances for display/discussion

Section II: Hands-On

Materials:

lumber for batter boards
nails
string
hubs and lath
flagging
pencil and paper

Tools:

hard hats
safety glasses
gloves
hammers
sledge hammers
hand saw
marking pens/pencils
50' rag tape
6' engineers rule
4' level
transit/legs/plumb bob
level/legs/grade rod
"C" clamps (2 per batter board)

Equipment:

pipe lasers and targets
blower
batteries (12 volt)

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Equipment, Tools, and Materials (continued)

Section III: Class Room

video tape player and monitor
local plumbing codes
pencil and paper

Section III: Hands-On

Materials:

mechanical joints/gland packs
rags
sewer saddles
tapping saddles (water)
marking pens
soap stone/lumber crayon
repair couplings
pipe for cutting
pipe for tapping
corporation and curb stops (flare and/or compression)/curb box
teflon tape
type "K" copper tubing for services
PVC primer/cement
cut off saw blades for metal and concrete
mixed gas

Tools:

hard hats
safety glasses
gloves
ear plugs
shovels
brick hammers
box wrenches
pipe wrenches
crescent wrenches
ratchet/sockets
hole or keyhole saw
jigsaw/blades
drill/drill bits (slightly larger than jigsaw blade)
flaring tool
tubing cutter

Equipment:

tapping machine and bits (to match tubing/corporation/curb stop)
drilling and tapping bit lubricant
pipe saws/wrench
generator/lead cords

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Equipment, Tools, and Materials (continued)

Section IV: Hands-On

Materials:
manholes for invert exercises
mortar mix and/or pozzolan
mason sand
concrete shims
utility top castings (manhole, catch basin and valve box)
main line sewer pipe for lateral exercise
4" lateral pipe (type is instructor discretion)
couplers for lateral pipe
sewer saddles (gasket and/or glue fittings)
45° and 90° elbows (double bell and/or street elbows)
joint lubrication
rags

Tools:
hard hats
safety glasses
gloves
5' bar
shovels
torpedo levels
mortar mixing tools
finishing tools for inverts
string and/or straight edge
hole saw for cutting sewer saddle openings
jigsaw/blades
drill/drill bits (slightly larger than jigsaw blade)
wrenches (sewer saddles)

Equipment:
mortar mixer
wheelbarrows
water drums
5 gallon pails
gas
oil

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Equipment, Tools, and Materials (continued)

Section IVa: Hands-On

Materials:
pipe (type and amount dependent on exercise)
joint lubricant (dependent on pipe type)
test plugs
wood bracing
rags

Tools:
hard hats
safety glasses
gloves
bar/block of wood
shovels
pipe slings (dependent on pipe type)

Equipment:
excavator
pipe laser, battery, blower and target
compactor
air compressor/100' air hose (for testing)
air pressure control valve
tie wire/whipcheks

Section IVb: Hands-On

Materials:
pipe (type and amount dependent on exercise)
pipe fittings and appurtenances (bends, hydrant, valves, etc.)
joint lubrication and gaskets (must be non-toxic, water soluble)
eye and tee bolts
all thread, washers and nuts for tie rods
4" x 2' x 2' pre-cast concrete for thrust blocking
copper tubing, corporation and curb stops for bleeders

Tools:
bar
shovels
wrenches
brick hammer
pipe sling
transit/legs/plumb bob
level/legs/grade rod

Equipment:
excavator
tapping machine and bits
compactor
test pump and gauges
test pump suction hose/5 gallon water reservoir

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The following is a list of hands-on exercises to be completed during the 80-hourPipe Laying class schedule:

Pipe Laying Section I: Trenching and Excavation Safety

I) Hydraulic Shoring ..... ❑

I) Screw jack Shoring ..... ❑

I) Timber Tight Shoring ..... ❑

I) Trench Box Set-up (optional) ..... ❑

I) Hazardous Atmosphere ..... ❑

Pipe Laying Section II: Pressure Pipe Laying Techniques

II) Pipe Saw Operation ..... ❑

II) Repair Couplings:

Dresser ..... ❑

Wrap-around ..... ❑

II) Water Line Installation ..... ❑

II) Hydrant Assembly ..... ❑

II) Test Pump Set-up ..... ❑

II) Tapping and Service Connection ..... ❑

II) Pipe Fusion ..... ❑

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Pipe Laying Section III: Utility Line and Grade

III) Transit and Level Set-up ..... ❑

III) Plumbing: Transit over offset stake, measuring techniques, installation of offset hubs ..... ❑

III) Level: Elevation of Bench Mark, offset hubs, flow line, cut sheets ..... ❑

III) Batter Boards ..... ❑

III) Level Loops ..... ❑

III) Plumb Transit: Align with centerline

Laser: T-Bar in Manhole ..... ❑

Top of Manhole ..... ❑

Through Pipe ..... ❑

Pipe Laying Section IV: Gravity Flow Piping Systems

IV) Sanitary Installation ..... ❑

IV) Low Pressure Air Test ..... ❑

IV) Saddles ..... ❑

IV) Repair: Fernco or Mission Couplings ..... ❑

Manufactured Slip Couplings ..... ❑

IV) Pour Manhole Inverts ..... ❑

IV) Storm Installation ..... ❑

IV) Subdrains and Subsoil Drains ..... ❑

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Instructor's Reference Notes for Classroom Discussion

Section I: Trenching and Excavation Safety

1) Review the terms and definitions and answer any questions the trainees may have.

Worker Protective Systems

1) It is very important to stress the fact that even though the OSHA regulations are enforced to protect the rights of workers, **"It is important that you understand that you are ultimately responsible for your own safety."**

2) OSHA Construction Standards 1926.650, 1926.651 and 1926.652 deal specifically with trenching and excavation operations.

3) Encourage the trainees to review and study the regulations included in Appendix B.

Figure 1-2 Screw Jack

1) Discuss the fact that screw jacks designed for shoring are available; they have swivel sockets on each end for alignment; they have nubs on the outside of the shoes that will embed themselves in the shoring lumber; and they should be nailed to eliminate movement.

2) The screw jacks have to be installed in a level position, the trench walls have to be solid at the time of installation and at a 90° vertical angle. You can substitute scaffolding screw jacks and base plates with the use of a spreader pipe. **"Plywood should not be used for skeleton shoring," unless uprights and/or walers are incorporated in the design.**

3) Install the shoring from the top down and when removing the shoring, work from the bottom up.

Figure 1-3 Timber Tight Sheet Shoring

1) When installing timber tight sheet shoring, make sure that the 45° chamfer is positioned with the long point away from the cribbing. If not installed correctly, the uprights will work there way inside the cribbing when they are driven into the ground.

2) When backfilling the sheet shoring, make sure that the fill is placed in equal amounts on both sides of the shoring so that the shoring does not shift out of alignment or level.

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3) All driving of the uprights should be done from outside the shoring, if needed, scaffolding should be set up to accommodate height differences.

4) Most contractors will elect to open cut or use a trench box instead of sheet shoring because of the production schedule and the time factor involved in timber sheet shoring. This type of sheeting is used mainly for underpinning of structures and for work that may take along time to complete in one area.

Figure 1-4 Hydraulic Shoring

1) When using hydraulic shoring, check the manufacturer's required pounds per square inch pressure for the shoring you are using. This will determine whether or not you have a safe trench in the immediate area of installation.

2) The same basic rules apply to hydraulic shoring, as well as skeleton shoring. They must be installed in a level position and the trench walls must be solid and at a 90° vertical angle to reduce the chances of dislodgment.

3) Stress the importance of where the pinch points are and how to handle the shoring properly. Check and make sure that the necessary tools are readily available and are in safe working condition.

4) When removing the shoring, check to see if every person is out of the trench in the area of removal and that the shoring is handled and stored correctly.

5) When using skeleton shoring, the only protection available to the workers in the trench are where the shoring has been installed. Any portion of the trench that is not shored is a potential hazard for cave-ins.

Figure 1-5 Hydraulic Wales

1) The hydraulic wales are installed from the top and removed from the from the top. The same precautions apply to the hydraulic walers as would apply to the hydraulic shoring.

2) Notice that this type of hydraulic shoring can be used for skeleton or tight sheet shoring.

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Sloping of Excavations

1) Discuss the sloping requirements for the different types of soils.

2) Discuss the four options available to the contractor and the use of the timber shoring tables in Appendix C to Subpart P page 180-185.

3) Use the examples on page 177-179 to enforce the proper use of these tables.

4) Discuss the hydraulic shoring tables in Appendix D to Subpart P on pages 191-194.

Excavations: Inspections and Frequency

1) Discuss the importance of daily inspections, prior to work beginning and throughout the shift.

2) Inspections by a competent person must also be conducted after every rainstorm or other hazard increasing occurrence. A hazard increasing occurrence maybe the sudden change in soil type, the freeze-thaw effect in certain climates, surface tension cracks, vibration from heavy equipment and the natural separation of the trench walls from the existing ground.

3) Discuss the different colors used by utility companies to mark the locations of existing utilities.

Electric: Red Paint
Telephone: Orange Paint
Gas: Yellow Paint
Water: Blue Paint
Sewer: Green Paint

4) Stress the point that if a cave-in occurs, the top man should immediately call for help. A topman should not leave the excavation or **take his/her eyes off of the last known location of the buried worker(s).**

Hazardous Atmospheres

1) Discuss the fact that Hydrogen Sulfide smells like "rotten eggs" in low concentrations and **that in high concentrations the sense of smell will be quickly paralyzed by the action of the gas on the respiratory center and cannot be relied on for warning.**

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2) Discuss the placement of equipment in or around an excavation project concerning gas engines and carbon monoxide. The inadequate placement of equipment can result in the emissions from the engines entering the trench and overcoming the workers.

3) The exhaust from diesel engines is colorless, odorless, and is heavier than air. With this gas being heavier than air, it can be expected that the possibility of the exhaust entering at a distant location and traveling the pipe line to the manhole that work is being performed in.

4) Discuss the routine maintenance of equipment to minimize the concentrations of exhaust fumes.

5) When testing a confined space, samples should be taken approximately every 12" to 18" inches all the way to the bottom of the space.

6) If standing water is present in the test area, it should be stirred up and tested again for hydrogen sulfide. The hydrogen sulfide will be absorbed in the water and will not be detected until it is released by movement of the water.

7) **Under no circumstances should a worker be in a confined space with out the space being tested before they enter. The confined space should be continually tested throughout the work process and a monitor should be present throughout the duration of the work.**

8) Instruct in detail the MSA 360/361 hazardous atmosphere sensor and the proper testing and calibration set-up of the instrument.

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1) Review the terms and definitions and answer any questions the trainees may have.

Crew Responsibilities

1) Discuss the responsibility and job description of each and every crew member **including the safety** of the crew and the public.

2) The top man, on most crews, will be responsible for backfilling the pipe after the initial bedding is placed. It is **very important** that the trainees understand that when backfilling the trench. They need to be aware of everyone in the trench, what direction they are moving in, and they should be positioned between the backfill operator and the crew members in the excavation. This will prevent the accidental dumping of backfill material on top of the other crew members and eliminate a potential hazard or serious injury.

3) The top man will be responsible for all signals outside of the trench until the materials are in the physical control of the lead man, than the only person that will signal will be the lead man. **Only one crew member should be signaling at any given time.**

4) The tail pipe layer will back fill and compact the initial bedding and move all tools and equipment ahead as the lead pipe layer works with the excavator operator to maintain line and grade.

Pipe Parts and Appurtenances

Figure 2-1 Flaring Tool

1) Type "K" copper tubing is a very soft copper. Too much pressure on the cutting wheel of the tubing cutter will indent the copper and make de-burring the cut more difficult.

2) All flare connections **must be de-burred** before the flaring tool is inserted.

3) The flare nut(s) are installed on the copper tubing before the flaring tool is inserted into the copper.

4) When flaring type "K" copper, it may be necessary to lightly tap the flaring tool to get it started into the copper.

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5) Once the tool is inserted, it is a good practice to grip the copper as close to the flaring tool as possible to eliminate the bending or mushrooming of the soft copper.

6) The flaring tool should be rotated every 2 to 3 hits from the hammer.

7) Check to make sure that the copper seats all the way into the groove at the top of the flaring tool.

Figure 2-2 Three-Part Union

1) The three-part union shown is a flare fitting. This can be purchased as a compression three-part union also.

2) Display a flare and a compression fitting to show the difference between the two types.

3) A compression union maybe necessary when a live repair needs to be completed.

4) The flare actually prevents the copper from being pulled or forced from the fitting, as well as providing a soft seat to seal the connection.

Figure 2-3 Corporation Valve

1) The corporation valve shown is a compression corporation valve.

2) Display and discuss the features of the compression fitting.

3) A compression connection does not need to be flared, but should be de-burred. The spring side of the rubber gasket faces the fitting, and the steel ring inside the gasket clamps around the copper tubing to help prevent the copper from being pulled or forced out of the fitting.

4) The copper will be inserted all the way in on a compression corporation and halfway in on a compression three-part union.

5) Corporation valves are always installed in the closed position and then buried in the open position when the line is ready for service. Check and make sure that the valve is in the closed position before any installation begins.

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6) Explain to the trainees that the side of the corporation valve that is installed into the main has tapered threads. If the corporation valve has to be removed and plugged, **it must be plugged with a tapered corporation plug.** A standard pipe thread plug is not tapered and will only allow a couple of the threads to enter the main, and then it will tighten up. The chances of the plug being forced out of the main from the pressure greatly increases the possibility of a serious injury or major problem.

7) All threaded fittings, whether compression or flared, should be teflon taped. This acts as a secondary seal on the fitting.

8) Whenever working on pressure lines, **never** work in front of the fitting or cap. **Never** take for granted that the line has been depressurized, even though the line has been shut off. There maybe residual pressure still in the line. If at all possible, bleed off the pressure.

Figure 2-4 Tapping Saddle

1) The tapping saddle can be used for repairs on lines where the corporation valve has been broken off. The tapping saddle has a rubber gasket on the inside of the saddle that makes the seal. The area where the saddle is to be installed must be cleaned, and on older lines, the area where the gasket makes contact may need to be wire brushed.

2) The tapping saddle is lined up with the existing hole. The U-Bolts are tightened up evenly to the required torque. When tightening the U-Bolts, make sure that the saddle stays in line with the existing hole.

3) The tapping saddle can also be used to drill a main line for a water service. The saddle is installed on the main line, then the corporation is teflon taped and inserted into the tapping saddle. A Mueller E5, D5, or PL2 drilling machine is threaded onto the copper tubing side of the corporation, and the corporation valve is opened. The drill bit is lowered through the corporation to the pipe and a hole is drilled into the main. The drill bit is retracted up through the corporation, and the corporation valve is turned off. The machine is removed and the corporation valve is flushed of any cuttings or debris.

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Figure 2-5 Curb Valve

1) The curb valve shown is a compression curb valve. Point out that the valve is a stop and waste valve with an "arrow" and "in/out" marked on the side of the valve.

2) This valve, when installed, should be placed on a flat rock or a solid concrete block. This will reduce the chances of the valve and valve box riser settling.

3) The valve has a valve box riser that is adjusted to the finished grade. There is a operating rod that is attached to the valve with a cotter pin. The cotter pin should be made of brass. A steel cotter pin will eventually rust and break allowing the operating rod to separate from the curb valve. In an extreme emergency, a heavy gauge copper wire may be substituted for the cotter pin.

4) This valve is the only shut off for the residence or business. If this valve is not installed properly or the valve is old and inoperable, the only choice available is to shut down the main line or to locate the corporation valve, dig up the main, and shut the corporation valve off.

5) The compression curb valve can be used to repair a live broken section of a water service. The valve can be installed on the feed end of the line, and then shut off to stop the flow of water.

Figure 2-6 Tee Bolts, Eye Bolts, and All-Thread

1) Display the tee bolts, eye bolts, and all-thread.

2) Discuss the difference between the regular tee bolt and the valve tee bolt. Valve tee bolts should be used for valve installations only.

3) During installation, it maybe necessary to use a brick hammer to hold the valve tee bolts and the eye bolts in position until they are tight.

4) Discuss the purpose and positioning of the eye bolts and all-thread.

5) A common practice is to take a brick hammer and burr the threads directly behind the nuts on the all-thread. This will prevent the nuts from loosening up during normal operating pressure surges and still will allow you to remove the nuts if necessary.

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Figure 2-7 Wraparound Repair Clamp

1) The wraparound repair clamp has to be wide enough to allow at least 2" to 3" each side of the crack or hole for an adequate seal.

2) The area of repair has to be thoroughly cleaned of any dirt or debris and may have to be wire brushed to a smooth exterior for a good seal.

3) Measure the total width of the repair clamp and divide in half, from the center of the hole or crack measure off to one side and make a centering mark. This mark when lined up to the edge of the repair clamp will make sure that the hole or crack is in the center of the wraparound repair clamp.

4) The tightening sequence of the wraparound should start in the center of the repair coupling and work toward the outer edges of the clamp. This sequence is repeated until the wraparound is secured and sealed.

5) After the repair is installed, the pressure is turned on and a visual check for leaks should be performed.

6) The bolts on the repair clamp should be positioned on the side of the section of pipe that is being repaired. If the section of pipe has to be exposed again, the bolts are not higher than the top of the pipe and the chances of tearing the clamp off the pipe are reduced.

Figure 2-8 Dresser Coupling

1) The dresser coupling requires the same cleaning of dirt and debris as with the wraparound.

2) Remove the bolts and show the beveled edge of the body and the bevel of the gasket. Explain that the tightening of the flanges forces the beveled gasket into the beveled body to form the watertight seal.

3) The damaged section of pipe has to be completely removed. A measurement is taken between the two existing ends of the pipe. The pipe is cut 1/8" to 1/4" smaller than the dimension just measured.

4) Measure the width of the dresser coupling and divide in half. Make a centering mark on both ends of the existing pipe. The repair pipe is cleaned and the dresser couplings are slid onto the repair piece. The repair section is placed in-line with the existing pipe, and the dressers are slid over the cut ends to the centering marks.

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5) The sequence for tightening the bolts is to go to opposite bolts for a few rotations, then go in sequence a couple of complete rotations. The bolts have to be tightened in equal amounts to properly seat the gaskets. To obtain final torque on the bolts, it maybe necessary to repeat the rotational tightening of the bolts several times.

Mechanical Joint Assembly

1) The bell and spigot ends of the pipe must be clean and free of any dirt or debris.

2) Mechanical joints do not need to be beveled.

3) When seating the gasket, start at the bottom of the pipe and work your way up to the top of the pipe. This will allow easier seating of the gasket. It is always easier to pound the gasket in on top of the pipe, then it is underneath the pipe.

4) It is extremely important that the trainees understand the tightening sequence of mechanical joints. This can determine whether the joint will leak or not. A flange that is not drawn in evenly will bind on the pipe. The bolts will seem to tighten up, once the backfill is dropped onto the pipe. The vibration could shift the flange and the gasket will become loose and more than likely leak.

Figure 2-9 Mechanical Joint

1) Point out to the trainees the beveled seat of the bell, the beveled gasket, and the part of the flange that forces the gasket into the bevel. **Note** the space between the flange and the spigot, the trainees must understand the flange has to be centered on the gasket between the bell and the spigot.

2) Stress the point that the bolts have to be tightened in even increments. Explain to the trainees that if they pay attention to the distance between the flange/gland and the bell of the pipe or fitting, they can see if the flange is being drawn toward the bell evenly.

Tyton or Push-on Joint Assembly

1) **Any potable water distribution system using the Tyton joint (slip-on/push-on) must be beveled. The gasket seat in the bell and the spigot have to be clean and free of any dirt or debris. The joint lubrication required for this type of installation must be *NON-TOXIC, and WATER SOLUBLE.***

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Figure 2-13 Tyton Joint

1) Discuss the graphic in detail, including the importance of having a smooth bevel, the gasket seat clean and free of any dirt or debris, and the parts of the joint that require lubrication.

2) Discuss the different bell types. The bell shown has a bead in the seat to center the gasket and help keep it from sliding or rolling. Another type of bell does not have the bead. Either way, the proper cleaning and installation of the gasket is equally important.

3) Bell holes need to be dug to allow the spigot end of the pipe to be inserted into the bell free of any dirt or debris.

4) The length of ductile iron pipe will vary, the pipe is actually cut to length by the weight of the section. The actual measurement of the pipe could be from 17' to 19', but the average laying length is 18' per joint.

5) One length of ductile iron pipe could weight upwards of 400 lbs. depending on the diameter of the pipe. When lifting a length of pipe with a wire rope choker, the open end of the choker hook points away from the pipe. The choker must be centered on the pipe so the pipe hangs level when lifted.

6) When the pipe is lowered into the excavation, it should be lowered as level as possible. If the pipe is not level, the chances of the wire rope choker rolling up the pipe greatly increases. Depending on which way the choker rolls will determine one of two results. The first being that one end of the pipe becomes extremely heavy, or the choker rolls completely off the pipe resulting in an **uncontrolled** free falling pipe.

Common Water Pipe Installation and Assembly Techniques

1) The open end of the pipe must always be covered with a shovel or piece of wood to prevent any unwanted materials from entering the pipe and causing problems later. This includes during installation, breaks, lunch, or at the end of the shift.

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Figure 2-14 Main Line Plan View

1) Review the Legend for Figure 2-14, and locate the symbols on the plan view.

2) Locate the design features on the plan view as they are referenced in the text. All valves and hydrants have to be installed level and plumb.

3) Discuss the abbreviations used in Figure 2-14.

For example: **68 L.F. 8" D.I. / S=+ 0.012 ft./ft.**
Sixty Eight Lineal Feet of 8" Ductile Iron Pipe at a slope of Plus 0.012 foot per foot.

Figure 2-15 Valve Riser

1) The valve riser box allows access to the main line gate valve. The valve can be opened or closed from the surface without the existing ground being disturbed.

2) The valve box must be centered on the operating nut of the gate valve. The valve box has to be back-filled level and plumb, and the top has to be set at finished grade.

3) Each section of the valve box has a little lip on the bottom. This lip, approximately 1/2" to 1" in width, is the only support for each section. Compaction is very important because the backfill holds the valve box risers to the finished grade, without the required compaction. The sections of the valve box will settle.

4) When the valve box settles, misalignment can be the result or the valve box is not at the right height for finished grade. No matter what happens, the only way to fix the problem is to dig up the riser, re-set the riser and re-compact the fill. So a little extra care toward the compaction around the valve box riser(s) is well worth the time spent.

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Hydrostatic Testing Procedures

1) Hydrostatic testing is the first test performed on a main line water service. There is actually three tests on the line before the line is put in service.

2) The second procedure in this series of test is to pump chlorine into the line. The chlorine cleans the line of bacteria and fungus. After a chlorinated sample is taken from the line and determined that the required amount of chlorine has been pumped into the line, the line is allowed to sit idle for 24 hours.

3) After 24 hours, the chlorine test is performed again. If the sample passes, another sample is taken and sent to a independent laboratory for a bacteria test.

4) The lab will test the sample for bacteria and send or phone the results to the contractor, project owner, project manager, and/or the local municipality.

5) After the series of test are completed and passed, the line has to be completely and thoroughly flushed of all chlorine. **The amount of chlorine pumped into the line, to disinfect the line, is enough to seriously injure and/or kill several people.**

6) The line is now ready to be put in service.

Mueller B-100 and B-101 Drilling and Tapping Machine

1) The feed nut and yoke are used to apply pressure to the boring bar when drilling the pipe. **Do not apply pressure to the boring bar when tapping the threads or when installing the corporation valve.**

2) The bit lubrication supplied with the machine is the only lubrication that is to be used for drilling and tapping a main line. The use of any other lubrication can contaminate the line or destroy the drill bit.

3) The Mueller Tapping machine can be used for live (wet) taps or dry taps. It really doesn't matter except for a few procedures like the flop valve doesn't have to be closed and the pressure doesn't have to be released.

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Operating the Portable All-Purpose Saw

1) The pull rope is the only way to start the saw, teach the trainees the proper starting and stopping procedures for the saw at your site. When starting the saw, the rope is pulled until a resistance is felt, then a quick pull of the rope turns over the engine. **Do not allow the trainees to let the rope snap back freely or allow the trainee to pull the rope out to the end of the pull rope.**

2) When cutting with the saw, the saw will be operated at full throttle.

3) Under no circumstances is a damaged abrasive or any other cutting wheel to be used. The rotational speed of the saw will shoot out a damaged piece of the cutting wheel at a very high velocity.

4) When beveling with the saw, the side of the blade is the portion to use. Using the cutting edge of the blade can chip the blade and send pieces flying in any direction at a high rate of speed.

5) The cutting and beveling of ductile iron pipe is a very important part of a pipe installation. The cut has to be as square as possible so the spigot end of the pipe comes in contact with the gasket at the same time on all surfaces. The bevel has to be as smooth as possible to eliminate cutting of the gasket.

Polyethylene Pipe Fusion Techniques

1) Ground Fault Circuit Interrupters should be used on all electrical connections.

2) The climate and temperature will effect the heating and cooling times.

3) The cleaning of the pipe ends should be with a clean, lint-free cloth. Some manufacturers and gas companies recommend the use of isoproponal to decontaminate the plastic. If the isoproponal is used, rubber gloves are required to protect the hands.

4) Do not allow the trainees to touch the ends of the pipe with their bare hands, dirty gloves, or dirty rags.

5) Allow enough time for the fusion to cool down before the pipe is released from the alignment jaws. You should be able to hold your finger on the fusion for an indefinite amount of time, without getting burned, before the pipe is released. The thumb nail test is a good indication that the joint has cooled sufficiently.

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Figure 2-41 Double Bead

1) Point out to the trainees that the 1/8" to 3/16" maximum height of bead.

2) This type of pipe can have a wide variety of applications, one that it is not good for is a gravity flow sanitary sewer. The reason is that the same size and amount of melted bead on the outside of the pipe, is the same size and amount on the inside of the pipe.

3) The actual fusion joint is stronger than the rest of the pipe. When the pipe is fused together, the wall thickness in the area of the joint becomes thicker than the wall thickness of the rest of the pipe.

4) Following the manufacturer's suggested heating and cooling time will help to insure a quality, long-lasting gas line, with minimal interruptions in service to the consumers in the future.

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Section III: Utility Line and Grade

1) Review the terms and definitions and answer any questions the trainees may have.

Construction Measurements

Figure 3-1 Horizontal Measurement

1) Discuss the proper procedures for length measurements, tape held without sag, held level and in line with the points to be measured. Demonstrate in the classroom the difference in measurements when the tape is not held level and the tape is sagging.

2) Demonstrate the transfer of length measurements with the plumb bob or by dropping an object. If an object is used for this demonstration, drop two objects from the same measurement to show the trainees that the objects hit the same spot.

Figure 3-2 Differential Leveling

1) Review the illustration on page 72.

2) Explain to the trainees the set-up of a level or transit (a transit can be used as a level), and the correct way to read a grade rod.

3) Explain to the trainees that after a level is set-up, the cross hair will stay at the determined elevation as long as it is not moved or kicked, and that it doesn't matter which direction the level is pointed in.

4) Make sure that the trainees understand that the higher the number they read on the grade rod, the lower the object is below the cross hair, and that the cross hair is a vertical reference for control of project features.

5) A level set-up in the class room may make it easier for the trainees to understand how the level cross hair is used for a vertical reference and how the grade rod re-acts to the cross hair.

6) Explain to the trainees that the grade rod is used to measure a vertical distance between the cross hair in the level and the object that the **bottom** of the grade rod is placed on.

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Common Referencing Methods

Figure 3-3 Reference Point Stake

1) Review the illustration on page 73. Point out the markings on the stake, the number 10 in a circle, the letter C for cut on the stake with the number 6 with a slash under the number 2. Notice that the ground slopes in the illustration and that the actual amount of cut maybe only about 3 or 4 feet. Discuss the station numbers and elevation of the hub, and that the cut of 6.2 feet is to the flow line of the pipe not the bottom of the manhole.

Figure 3-4 In-Line Referencing

1) In-Line referencing can be set at any angle from the object being referenced as long as both stakes are set in a direct line and at a predetermined distance to the object being referenced.

Figure 3-5 Right-Angle Referencing

1) Right-Angle referencing is a common practice on pipe jobs. The reference line will be set with a transit to keep it in a parallel line with the center line of the pipe.

2) The transit will be set up on one end point and sighted in on another end point. Then the transit will be turned to a 90° angle from the center line and a stake will be set at a predetermined offset.

3) The transit is moved to the end point that was sighted in the first set-up and centered over the hub. Then the transit is locked on to the first hub that was set-up over and turned to a 90° angle from center line, and a stake is set at the same off-set distance.

4) The transit is moved to the offset stake that was just set and set-up over the hub. Then the transit is sighted in on the other off-set hub and stations are set between the two offset stakes.

5) Anytime the layout has to be precise, the project feature has to be laid-out and should be located from at least two points. For instance, the center line of the pipe in Figure 3-5 is at a predetermined offset of 10'. One measurement, and the second measurement can be the diagonal from the nearest station.

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Figure 3-6 Swing Tie Referencing

1) Swing tie referencing can be used in a variety of different applications. The reference points picked for swing ties must be at approximately between a 30° and 45° angle.

2) These points must be to fixed objects that cannot be moved or disturbed for the entire duration the points are needed. For example a light pole, the corner of a house, a fire hydrant, or a secure fence post.

3) Demonstrate on the blackboard how the swing ties arcs can touch over a long distance or how the arcs may crossover each other twice in the same area making it difficult to determine where the feature actually is.

Table 3-1 Inch to Decimal Conversion

1) Teach the trainees the decimal conversion for every quarter of a foot. For example: 1/4 of a foot is equal to 3", so 3" is equal to .25 or 1/4 of 1.00; 1/2 of a foot is equal to 6", so 6" is equal to .50 or 1/2 of 1.00; 3/4 of a foot is equal to 9", so 9" is equal to .75 or 3/4 of 1.00; and 1 whole foot is equal to 12", so 12" is equal to 1.00 or one whole foot.

2) Once the trainees have memorized the 1/4 foot increments, .25', .50', .75', and 1.00', it is very easy to find the decimal equivalent for each inch. You simply determine which 1/4 of a foot decimal equivalent is closest to the inch in question and either add or subtract .08 from the quarter foot increment. For example, if I wanted to know the decimal equivalent of 5", well the closest 1/4 foot increment is 6" which is equal to .50, and since 5" is one inch **less** than 6", I'm going to **subtract** .08 from .50 and have an answer of .42 which is equal to 5". What if I needed to know what the decimal equivalent of 7" is, well 7" is one inch **more** than 6", so I'm going to **add** .08 to .50 and have an answer of .58 which is equal to 7".

3) The key words for this method is the inch in question. Is the inch **more** or **less** than the closest quarter of a foot increment? If the inch in question is **more** than the quarter of a foot increment, than **the .08 is added** to the quarter of a foot increment. If the inch in question is **less** than the quarter of a foot increment, **the .08 is subtracted** from the quarter of a foot increment.

Converting Between the U.S. Standard and the Decimal System

1) The 1/8" = 0.01 ratio is not exact due to the rounding, 1/8" is actually equal to 0.01333. The 1/8" = 0.01 ratio is accurate enough for our type of work as long as this ratio is used to convert less than one inch at a time.

2) Any fraction that is expressed with eight as the denominator, automatically gives you the number of hundredths in the numerator.

   For example: 5/8" is equal to 0.05, and 3/8" is equal to 0.03

3) Discuss the conversion procedure for changing fractions that are not in eights to fractions that are in eights.

Stationing System

1) The stationing system in the United States is based on 100' increments.

2) Any time a station number has a plus sign in the number, it is describing a physical location on the job site. When the plus sign is dropped from the station number, it is describing a horizontal distance from the beginning station.

Figure 3-7 Stationing Location

1) Review the illustration on page 87, and be sure to point out the thousands, hundreds, tens, ones, tenths and hundredths.

2) Discuss all the abbreviations used in this section, and be sure that the trainees understand them.

   For example: Sta., 0+00, a wavy line instead +00 and +50.

Written Instructions

1) Some of the costly mistakes on a construction site are because the blueprints were misinterpreted. The time spent on the blueprint protocols is very important. Every person on the job, whether the job is on the east coast or the west coast, have to read and understand what the architect has designed, the location of the design feature, and the elevation change or changes.

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Figure 3-8 Stationing Location

1) Directions such as: Up (+), Down (-), Right (RT), Left (LT) must be interpreted the same by all who work with them. This protocol makes every written direction based on what is called **AHEAD Station.**

2) When you are facing the direction the station numbers increase, you are facing the **AHEAD STATION.** If you are facing the direction the station numbers decrease, you are facing **BACK STATION.**

3) **Ahead** station is also known as **up** station and **Back** station is also known as **down** station.

4) If you are facing in the **ahead** station direction, **right** side of the project is on your **right** side and **left** side of the project is on your **left** side. If you are facing in the **back** station direction, **right** side of the project is on your **left** and **left** side of the project is on your **right**.

Figure 3-9 Stationing Location

1) The same protocols apply to up or down. If you are facing in the **ahead** station direction, **up (+)** means the elevation is going to **rise** between the station you are at and the station you are facing. **Down (-)** means the elevation is going to **fall** between the station you are at and the station you are facing. If you are facing in the **back** station direction then the **up (+)** will actually mean that the elevation is going to **fall** and the **down (-)** will actually **rise.**

2) So as a brief summary,

When facing the **AHEAD STATION DIRECTION**:

Right is Right
Left is Left
Up is Up
Down is Down

When facing the **BACK STATION DIRECTION:**

Right is Left
Left is Right
Up is Down
Down is Up

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Squaring Principles

1) The formulas depicted in the following illustrations are two basic layout tools that can be applied to a wide variety of situations. The formulas have to be completely understood by all trainees. The instructor should give extra examples for classroom exercises to enforce the concepts and application of the formulas.

2) It is suggested that, if time permits, a few hands-on exercises will help the trainees to understand the formulas so that they can apply them to different situations. The squaring formulas can be used for layout of small buildings, curb lines, center lines, project features, or even a backyard patio.

Figure 3-10 Diagonal Length for a Square

1) The diagonal for a square is probably one of the easiest formulas to remember because of the multiplier of 1.414. This multiplier will not change. Anytime that the diagonal for a square has to be determined, simply multiply one side length of the square by the multiplier of 1.414 and the sum is the diagonal.

2) All diagonal measurements are longer than any side length of the object you are trying to find the diagonal for. Any diagonal measurement that is calculated and is not longer than the longest side of the square or rectangle is a miscalculation.

Figure 3-11 Diagonal Length for a Rectangle

1) $A^2 + B^2 = C^2$ is the formula for the diagonal of a rectangle. This looks very complicated when viewed by itself. The A^2, B^2, and C^2 is what makes this formula look so complicated. When there is a ^{2} following a number it means that the number is squared or multiplied times itself.

2) The formula is actually very easy. The first thing to do is to designate one side length of the rectangle as A and the other side length of the rectangle as B. Once this is done, it's just a matter of multiplying, adding the sums together, and then square root the sum.

3)

A^2 means that	**A times A = a sum**
B^2 means that	**B times B = a sum**
C is the sum of $A^2 + B^2$	**A plus B = a sum**

After the total of A plus B is calculated, push the square root key (√) on the calculator. The answer is the diagonal for a rectangle.

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Slope Expressions

1) The slope expressions described in the following text can be used in a variety of construction job assignments. The expressions, abbreviations, and the applications for Slope Ratio, Percentage of Slope, and Rate per Foot are three common expressions that a pipe crew utilizes everyday. The application, and relationship to pipe work, of these three expressions must be understood by everybody who will be working on a pipe laying crew.

Calculating Hub and Flow Line Elevations for a Cut Sheet

1) Cut sheets are pages of notes that describes the vertical distance from the hub or stake to the invert elevation of the pipe. The actual amount of material to be excavated may be more or less than the cut distance.

2) Cut sheets can also indicate if a fill is necessary and where. The foreman can look at a cut sheet and be able to determine the deepest part of the excavation, the location of that area on the project, if shoring is needed, the type of shoring preferred, or the sloping requirements determined by the type of soil and the depth of cut.

Figure 3-13 Hub and Flow Line Elevation/Table 3-5 Sample

1) The illustration depicted in **Figure 3-13** was designed to coincide with **Table 3-5: Sample Cut Sheet**. As you review Figure 3-13, refer to the sample cut sheet and locate where the entries are logged.

2) When reviewing Figure 3-13, point out the hub elevation, and the flow line elevation. The difference between the two is the cut or fill distance written on the stake and logged in the sample cut sheet.

3) Describe how the flow line elevations are calculated according to the distance between stations, and show the stake elevations are determined from the height of instrument.

4) If the **Stake Elevation** is a larger number than the **Flow line Elevation**, the distance between the two is a **Cut**. If the **Flow Line Elevation** is a larger number that the **Stake Elevation**, the distance between the two is a **Fill**.

6) Anytime you are working with elevations, the larger the numbers are the higher you are above Mean Sea Level (MSL) or Above Sea Level (ASL). Mean Sea Level is the average height between high tide and low tide.

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7) A brief description of the United States Geological Survey and above sea level may help the trainees understand the elevations and mean sea level. Most bridges have a U.S.G.S. plate imbedded in the bridge embuttments and the elevation stamped on the round plate is the actual elevation above sea level in that area.

Elevation Control

1) All projects have to have control points, these control points are called Bench Marks. The bench marks are points of known elevation from which all elevations on the job, above or below ground, will be controlled or set from.

2) The bench mark can be one of two kinds, either actual or relative. The first kind is the actual bench mark elevation above sea level. This bench mark is the actual known elevation above mean sea level in the area of the project.

3) The second is the relative bench mark. This kind of bench mark is an assigned elevation for control of the project features. This kind of control is a point of known elevation that is set by the survey crew to establish the elevation control needed to complete the project. This kind of control has nothing to do with the actual elevation in the area of the project.

Level Notebook

1) Level notebooks can be entered in court as a legal document, if the level notebook is filled out correctly. This section should be carefully instructed to insure that every trainee follows the correct procedures for an accurate notebook that will be legally acceptable.

2) There are six columns that have to be filled out in order for the level notebook to be legally entered in court as evidence. The columns are STATION, BACK SIGHT BS (+), HEIGHT OF INSTRUMENT (HI), FORE SIGHT FS(-), ELEVATION, AND COMMENTS.

3) Most of the columns are self-explanatory, Station, Height of Instrument, Elevation, and Comments. The two other columns that may need some extra explanation are Back Site and Foresight.

4) Backsight has a plus sign next to the letters BS. The plus sign means that any vertical measurement that is entered in this column will be added to the last known elevation or turn point. The back site column is used whenever the instrument is moved and a new height of instrument needs to be established.

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5) The Foresight column has a minus sign next to the letters FS. The minus sign means that any vertical measurement that is entered in this column will be subtracted from the last known height of instrument. The foresight column is used whenever an elevation of a project feature or a turn point needs to be established or documented.

6) In summary, Backsight entries are for when the instrument is moved and a new height of instrument has to be established. Foresight entries are for when the elevation of a project feature or turn point has to be established.

7) The level loops have to check back into the original or another established bench mark within 1 to 2 hundredths. Any deviation that is more than 1 to 2 hundredths is not legally acceptable and proves that either the instrument is out of calibration or there is a mistake in the math calculations.

8) The hands-on exercises for cut sheets and level loops should be completed, as soon as possible, after the instructional portion of the text is presented.

1) Review the terms and definitions and answer any questions the trainees may have.

Sanitary Sewer Systems

1) Sanitary sewer systems are used to collect waste products from businesses and residences. The waste products are transferred to treatment facilities through a network of gravity flow piping systems. The treatment facilities take raw sewage and chemically disinfect the waste to acceptable standards before the waste is released back into the environment.

Figure 4-1 Plan View-Proposed Sanitary Sewer

1) Review the illustration on page 112 as the text is presented. Point out the proposed sanitary sewer main line, the proposed manholes, the proposed laterals for each lot and the length and slope of the main lines.

Accuracy Requirements

1) Accuracy requirements will vary depending on the type of pipe, the size of the pipe and the local codes governing the installation of the pipe line.

2) The accuracy requirements are strict and must be adhered to for a trouble-free system with a long useful life span. If there is too much slope, the liquids will separate from the solids and create blockages. If there isn't enough slope, the force of gravity will not be strong enough to push the solids along the network of pipes and manholes to the treatment facility.

Figure 4-2 Gravity Flow

1) Gravity flow systems are always installed with the bell ends facing uphill or upstream, the flow should leave the spigot end and enter the bell end to have a smooth transition from one pipe to another. If the bells are installed in the opposite direction, or downstream, the chance of blockages forming greatly increases. The lip of the spigot end is exposed, against the flow, to whatever raw sewage that is transmitted down the line. This lip can stop the normal flow of the material and a blockage will occur.

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Table 4-1 Minimum Gradients to Permit a Flow of 2 Cubic Foot Per Second

1) This illustration is an example of the minimum percent of grade for different pipe sizes. The actual requirements in your area may vary depending on the local codes.

2) Two factors that will effect the performance of a gravity flow pipe when the system is installed are too much slope and not enough slope. When there is too much slope, liquids will separate from the solids. If there isn't enough slope, the force of gravity will not be strong enough to push the material to the treatment plant.

Pipe Types

1) Review the Figures 4-3 through Figure 4-7 in the Pipe Types section as the text is presented.

2) Discuss the pipe types:

characteristics of each (good and bad)

joining techniques

specific applications for the type of pipe

installation techniques and the availability of accessories, such as fittings, repair parts, slip joint or mechanical joint, mortar joint or primer/glue joint, and backfill precautions.

Installation Techniques

Figure 4-8 Initial Embedment

1) Review the illustration for pipe installations on page 115.

2) Discuss the terminology, springline of pipe, haunching, initial backfill, embedment material.

3) The haunching and initial backfill to the springline of the pipe is one important part of the installation procedures. The bedding material is compacted to reduce the possibility of settlement that will create low points or dips in the line.

4) The haunching and compaction of the bedding material to the springline of the pipe adds support to the pipe and reduces the chances of the pipe becoming egg-shaped from the weight of the backfill material.

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5) The pipe zone, which is from the subgrade to the top of the initial bedding including the total embedment material area, is the critical area of the installation process.

6) The correct procedures during the installation of the pipe and the adequate compaction reduces the possibility of settlement of the backfill material. The required compaction is necessary to avoid dips in a roadway and to eliminate breakage or squashing of the pipe due to the pressure exerted from traffic, or weight of the backfill material.

Table 4-2 Description of Existing Materials

1) The table on page 116 is a sample of soil classification. The classification in your state maybe slightly different depending on the availability of different soil types and/or backfill material.

2) Generally the classes of I, II, and III bedding material is commonly known as a **Select Fill.**

Haunching of Pipe

1) Bell holes are dug to allow easy installation of the next pipe. These bell holes have to be filled in after the pipe is installed and should be compacted with a T-bar, if one is available, or sometimes the handle of a short handled shovel.

2) After the bell area has been compacted, the rest of the bedding has to be compacted. When the pipe is first installed, the bedding is placed entirely along the length of the pipe to hold it in place. The initial bedding has to be compacted from the pipe to the trench walls on both sides of the pipe.

3) Sometimes, when the compaction process starts, the material is so loose that the compaction equipment can actually move the pipe out of line and grade. A good practice is to start your compaction at the trench walls and work in towards the pipe. This will trap the pipe on line and grade set by the leadman.

4) Make a couple of passes along one side of the trench and then move over to the other side and repeat. The trench walls resists the movement of the backfill and adequate compaction is started, this allows the bedding material to compress and trap the pipe in the originally laid position.

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Purpose of Manholes

Figure 4-10 Typical Manhole

1) Review the illustration on page 118 in detail.

2) Note that the frame and cover have a dust pan to help keep dirt and debris from entering the manhole.

3) Note that there is a 24" minimum and a 48" maximum height allowance on the precast concrete eccentric cone.

4) Note that there is concrete adjusting rings in the illustration. Solid concrete bricks can be substituted for the adjustment rings in most cases.

5) **Note that there is a 26" maximum height allowance from the frame and cover to the top of the eccentric cone. This requirement is to minimize the distance from the frame and cover to the first step, making the entry into the manhole easier and safer.**

6) Note the 25 1/2" entry opening in the eccentric cone section. Make sure the trainees visually check the condition of the steps in the manhole especially if the manhole has been in use for any length of time. Generally, the steps are set at 12" on center and at 90° to the flow line in the manhole.

7) The 48" precast concrete riser is, in most cases, the inside diameter of the manhole.

8) Most direction changes, in a sanitary sewer line, will be done at a manhole. Bends or fittings in a sewer line can hamper the flow and create blockages.

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Drop Inlets

1) Review the illustration on page 119 in detail.

2) The side bore of the tee fitting is pointed down to allow the material to enter the manhole at the springline of the main when exiting from the 90° elbow.

3) Blocking is needed between the drop inlet and the outside of the manhole to eliminate the movement of the drop and to securely strap it to the manhole.

4) Most specifications will require that the strapping material be made from stainless steel. The stainless steel resists rusting and breaking.

5) Note that anytime there is a drop of more than two feet, there will be a requirement for a drop inlet. When the drop inlet is 6' or greater, the drop inlet maybe required to be encased in concrete. Drop inlets can be ordered from the manufacturers already prefabricated.

Sanitary Sewer Cleanouts

Figure 4-12 Typical Clean Out Installation

1) Review the illustration on page 120 in detail.

2) The illustration shown is featuring Class 52 Ductile Iron Pipe. The cleanout can be assembled with other types of pipes and end caps.

3) Note the encasement in concrete, 24" in length and at least 4" minimum around the pipe.

4) Note the use of a 45° bend at the end of the line to start the rise to the surface. Usually a 45° or a 22 1/2° bend is used, not a 90°, for a gradual direction change. A sudden direction change, like a 90°, can hamper the insertion of cleaning devices.

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Installation of Laterals (Building Services)

Sewer Saddle Assembly Procedures

1) A drill and drill bit slightly larger than the width of the jigsaw blade can be used to start a pilot hole for the sewer saddle.

2) **Do not** allow the trainees to cut the service saddle hole any larger than necessary. The larger the hole in the pipe, the weaker the pipe is at that section.

3) Gasket saddles are preferred for this hands-on exercise because they can be reused. Solvent weld saddles are a one-time deal. The preparation procedures are the same, the only difference is the way they are attached.

4) The slope on the laterals is generally between 1/8"/ft. min. to 1/2"/ft. max. The problem with using the 1/4 bubble on a torpedo level is that a 1/4 bubble to one person maybe different to somebody else. By using a block of wood taped to a level, there is no deviation in slope because the pipe is set with the bubble reading level on every length of pipe.

5) A good practice on laterals is to **never** put bends (22 1/2°,45°,90°) together in succession, if a direction change is necessary, put a short pup (12"-18") between the bends. This will reduce the possibility of a blockage occurring from to sharp a direction change.

Repair and Tie-in Methods

Figures 4-16 through 4-18

1) Review the illustrations and the text in detail for repair methods.

2) After the repair is installed, there should be a visual check of the repair for leaks before the backfill is placed.

3) A caution about rubber couplings is that the fittings are extremely flexible. When installing these couplings, the subgrade has to be at the right elevation. The initial backfill is carefully placed and compacted to the required density to maintain the correct line and grade and to reduce the settling effect that causes misalignment.

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4) Double bell couplings are a rigid fitting with no flexibility at all. The replacement pipe has to be beveled. The double bell fitting and pipe have to be greased. The double bell coupling in usually placed on the repair pipe and then slid over the existing pipe ends and centered.

5) Polyvinyl Chloride (PVC) can be cut with a braided nylon mason string in situations where there is not enough room for a conventional saw.

Repair Procedures, Concrete Pipe Larger than 15" in Diameter

1) Review the text and Figures 4-19 through 4-21 on the concrete pipe repair.

2) Safety when rotating the pipe with a machine is the most important factor in this procedure.

3) All nylon straps, wire chokers or whatever is used to pick and rotate the sections of pipe have to be in excellent condition. Stress the importance of where the workers should be in the trench when this operation is performed.

4) Pry bars maybe needed to keep the replacement pipe in alignment during the rotating portion of the repair. **Never allow a trainee to position himself/herself in the danger zone of the trench.**

Low Pressure Air Testing of Sewers

1) Low pressure air test is a common test performed on a sewer line. This portion of the course needs to be supervised closely because of the pneumatic pressures applied to the test plugs and bracing.

2) The test plugs and pipe have to be braced to prevent blowouts and possibly a serious injury.

3) The plugs depicted in Figure 4-23 through 4-24 are inflatable test plugs. There is a mechanical type of test plug and should be displayed to the trainees to show them the difference.

4) These plugs are not limited to testing only. They can be used to seal off a line at the end of the shift to prevent any dirt, debris, or animals that may enter the pipe. If the plugs are utilized for this purpose, they should be tied off to a stake to prevent the plugs from being sucked into the line and becoming lodged inside the line.

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5) Most project owners or architects will require that the test be performed by an independent testing agency to avoid conflicts of interest.

6) **Under no circumstances is anyone allowed in the manhole or around the manhole during the test. No bracing or plugs are to be removed until you are *absolutely sure that the pressure has been completely released.***

7) The pressure test may not be the only test required on a new line. There are at least two more test that may be necessary. On some sewer lines, the owner may require that the line be inspected with a TV camera. The camera will be sent through the line and a TV signal will be sent to a van with a monitor inside. The actual image of the inside of the pipe will be recorded on video tape. Any dips (standing water) or misalignment will stand out and the section of pipe will have to be re-dug and fixed.

8) The second type of test that maybe required is an alignment and cylindrical test. This test is performed by hand pulling a mandrel through the line from manhole to manhole. (Mandrel is a ball made out of wood or steel that is slightly smaller than the inside diameter of the pipe being tested.)

9) The test requires equipment like a compressor, air hose, ball of string, and two lengths of rope long enough to reach from manhole to manhole, as well as a mandrel and a few small plastic grocery bags.

10) The bag is tied to the string line and acts like a parachute when the air is turned on and blown through the pipe from one manhole to the other. The rope is tied to the end of the string and pulled through the line. The mandrel is attached to the rope and a second rope is attached to the other side of the mandrel. Then the mandrill is hand pulled from one manhole to the other.

11) When pulling the mandrel, a back pressure has to be applied to keep the mandrel in-line. That is why the second rope is attached. If the mandrel gets stuck, you can pull it back to the starting point. If the mandrel can be pulled from one manhole to the other by hand, then the pipe is inalignment and compaction was adequate enough to keep the pipe from becoming egg-shaped from the weight of the backfill.

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Air Pressure Time Loss Calculations

1) Review the Low Pressure Air Test Time Table on page 128. Give the trainees extra examples to work on and check their answers.

2) Column A is for the Pipe Diameter in Inches.

3) Column B is the test time per foot for any diameter pipe up to the maximum length in Column C.

4) Column D is the total test time for any diameter pipe as long as the overall length is between Column C and Column E.

5) Column F is the test time per foot for any diameter pipe that is longer in length than the maximum length specified in Column E.

6) As discussed earlier, the contractor that installed the pipe line may be the one testing the line; but, it is not uncommon for the project owner to request that a independent testing agency perform the test to avoid a conflict of interest.

Invert Construction and Shaping

Figure 4-25 Invert Construction

1) Review the illustration on page 129 and discuss the importance of a smooth transition from the in-flow to the out-flow pipes.

2) Invert construction is the finishing touch on a sanitary sewer line. The invert has to be as smooth as a finished floor and maintain a pitch from the in-flow to the out-flow pipe to facilitate the gravity flow principles.

3) Invert construction that has more than one line entering must be shaped to force the material in the direction of the out-flow pipe.

Storm Drain Systems

Figure 4-26 Storm Drain Manhole

1) Review the illustration and point out that the in-flow lines are usually smaller than the out-flow line. The out-flow line has to be large enough to handle the combined accumulation of all the in-flow lines, plus what ever enters from the grate top on the catch basin.

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Accuracy Requirements

1) Storm drain systems are installed with the same basic accuracy requirements as a sanitary sewer line because they both use the gravity flow principles.

2) The one major difference between the two systems is that a storm drain system doesn't use invert construction. Instead, the storm drain system incorporates a sump.

3) The sump is usually 12" to 18" below the out-flow invert. The surface water enters the catch basin and has to build up to the out-flow invert. Any dirt or debris ends up settling in the bottom of the catch basin and a maintenance crew will periodically clean the catch basin.

4) The sump collects the dirt and debris and keeps it from entering the storm drain system and clogging the lines or restricting the flow.

Pipe Types

1) Review the Figures 4-27 through Figure 4-30 in the Pipe Types section as the text is presented.

2) Discuss the pipe types:

   characteristics of each (good and bad)

   joining techniques

   specific applications for the type of pipe

   installation techniques and the availability of accessories, such as fittings, repair parts, slip joint or mechanical joint, mortar joint and backfill precautions.

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Subdrains and Subsoil Drains

General Overview

1) Subdrains and Subsoil Drains are another form of a gravity flow system. Accuracy in the grading and installation of the system will determine whether the system will perform up to the expectations it was designed for.

2) The pipes used for this type of installation usually contains two rows of perforations approximately 15° each side of the flow line. The perforations are installed down to collect the water from the lowest point of the excavation.

3) The pipe is bedded completely in a washed stone. The stone is encased in a filter fabric to help prevent silt from entering the system and clogging the lines.

4) The first filter that the ground water passes through is the filter fabric. Then the water has to pass through the washed stone to the bottom of the excavation. Finally the water builds up enough to enter the perforations on the pipe and follow the flow line to a natural drainage area.

5) If the perforations are installed on top of the pipe, the water has to build up higher in the trench before it enters the pipe. The chances of the silt entering the pipe as the water filters down through the stone greatly increases.

Pipe Types

1) Review the Figures 4-31 through Figure 4-34 in the Pipe Types section as the text is presented.

2) Discuss the pipe types:

   characteristics of each (good and bad)

   joining techniques

   specific applications for the type of pipe

   installation techniques and the availability of accessories, such as fittings, repair parts, slip joint or manufacturer's couplings and backfill precautions.

Figures 4-32 and Figure 4-34

1) Review each of these illustrations in detail and answer any questions that the trainees may have. Point out the difference in the perforations in the two illustrations.

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SECTION I ASSIGNMENT SHEETS

Place the proper letter beside the correct definition.

a. Sloping

b. Wales

c. Sheeting

d. Benching

e. Trench

f. Competent Person

g. Slope Ratio

h. Uprights

i. Excavation

j. Cross Braces

___f___ means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

___i___ means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

___c___ means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

___d___ means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

___g___ means a horizontal to vertical relationship with the horizontal expressed first, and the vertical always expressed as one.

___a___ means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation to prevent cave-ins.

___e___ means a narrow excavation (in relation to its length) made below the surface of the ground.

___h___ mean the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not touch each other.

___b___ means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

___j___ mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, with the ends bearing against either uprights or wales.

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Match the following sloping requirements with the soil types:
(Many contractors use a ratio of 1 1/2:1,(Type C), for all excavations regardless of soil type.)

Sloping Requirements:	Soil Types: Review 1926.652 Appendix A, B, and Table B1
a. Vertical	b An excavation in gravel material with an unconfined compressive strength of 0.5 tsf or less.
b. 1 1/2:1	d An excavation 10 feet deep in cohesive soil with an unconfined compressive strength of 1.5 tsf (for only 12 hours).
c. 3/4:1	e An excavation in cohesive, fissured soil with an unconfined compressive strength of 1.5 tsf.
d. 1/2:1	e An excavation in cohesive soil with an unconfined compressive strength of 1.5, but was previously excavated.
e. 1:1	a An excavation in stable rock.

Answer the following questions:

1. What are three types of cave-in protection systems?

   Sloping, shoring and trench box.

2. Who is required to inspect an excavation?

   A competent person able to assess the situation and decide to make the necessary changes to remedy the problem.

3. When are these inspections required?

   Before the work begins, during the shift, and after any change that may create a hazardous situation.

4. Describe three warning signs of a pre-existing excavation or a buried utility.

   Drastic or sudden change in soil, garbage below the surface, utility marking tape.

5. Describe three types of hazardous atmospheres and physical characteristics for each.

   Methane Gas: Explosive, oxygen displacement, lighter than air.
   Hydrogen Sulfide: Low concentration rotten egg smell, flammable, heavier than air.
   Carbon Monoxide: Colorless, odorless, tasteless, from exhaust of gas engines.

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Answer the following permit required space questions:

6. Name three permit system requirements.

Rescue service.
Retrieval system equipment such as a rescue line, body harness, wristlets, lifting device.
Testing.

7. What is the definition of a confined space?

A large enough space that can be entered to work in.
Has limited or restricted means of entry or exit.
Is not designed for continuous employee occupancy.

8. When is a permit needed inside confined space?

Contain or potential to contain a hazardous atmosphere.
Contains a material that can engulf a worker.
Becomes smaller and smaller.
Contains other serious safety and health hazards.

9. When should you exit a permit space as quickly as possible?

An order to evacuate is given.
You recognize any warning signs or symptoms of dangerous exposure.
You find a prohibited condition.
An evacuation alarm sounds.

10. List the duties of a permit space attendant.

Stay outside permit space.
Keep accurate count of authorized entrants until replaced by another attendant.
Can perform rescue operations if trained and equipped for rescue operations and the permit entry program allows you to enter the space if another attendant is present.
Communicate with entrants, monitor their status.
Evacuate entrants.

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11. List four situations when an attendant must evacuate a confined space.

When you detect a prohibited condition.
Behavioral effects of hazardous exposure.
Dangerous situations outside the space that could endanger workers inside the space.
Cannot effectively and safely perform duties.

Answer the following back injury questions:

12. What is one exercise that can help keep your back healthy? How often and for how long should you perform this exercise?

Walking / three times a week / 20 minutes.

13. What is the most comfortable resting position when you have a back injury?

When in bed / laying on our side / pillow under head / pillow between knees / bring knees toward chin.

14. What are four symptoms of back pain that will help you decide to visit a doctor?

Constant pain with no relief at all.
Pain or numbness below the knees.
Involuntary release of bowel or bladder.
Any change in discomfort level.

15. When do construction workers usually hurt their backs and how can this injury be avoided?

On the first heavy lift of the day / can be prevented by a pre-work warm up.

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SECTION II ASSIGNMENT SHEETS

Describe the responsibilities of each person:

The lead pipelayer

Responsible for working with excavator operator.
Set line and grade .
Lowering of pipe into ditch.
Signaling in ditch.
Usually most experienced on crew.
Cave-ins.
Safety of crew.

The top man

Getting and rigging of all tools and materials.
String out of pipe and parts utilities locations.
Traffic.
Backfill.
Signaling outside of trench.
Cave - ins.
Safety of crew.

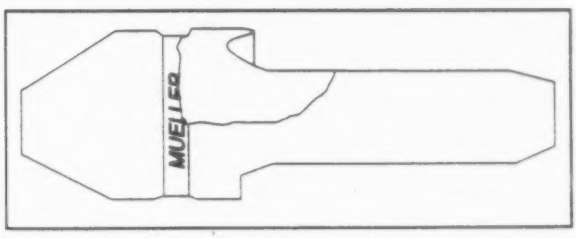
The tail pipelayer

Cleaning and lubrication of joints.
Tools in ditch.
Ladders.
Utilities in ditch.
Grade with lead man.
Stab pipe and perform initial backfill.
Cave - ins.
Safety of crew.

Identify each of the following illustrations:

1. **Tapping Saddle**

2. **3 - Part Flared Union**



3. **Impact Flaring Tool**

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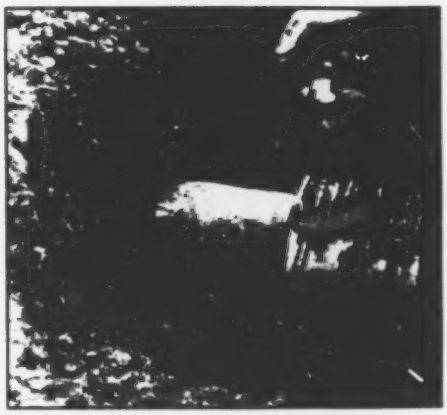
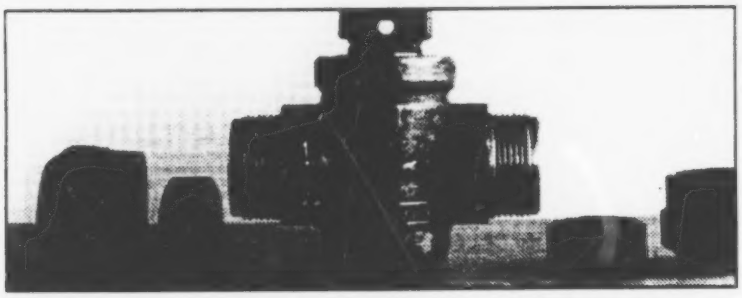
4. **Compression Corporation Valve**



6. **Wrap-Around Repair Clamp**



5. **Compression Stop and Waste Curb Valve**

Answer the Following Questions:

1. Does a mechanical joint require lubrication? **No.**
2. You should always tighten the bolts **opposite / evenly / sequence** when tightening a mechanical joint.
3. Before inserting a pup into a tyton joint, the cut should be **beveled** .
4. A fire line is usually required to be **all thread / rodded** to the main.
5. After a previously bolted fitting is lowered into the excavation and bolted into place, the pipelayers should always **recheck** the fittings.
6. What is a standard joint length of Ductile Iron Pipe? **18'.**
7. During back-fill of a fire hydrant and valve riser, both fittings must be constantly checked for **plumb / level** .
8. When should a main line gate valve be opened quickly? **never.**
9. What is a common test pressure and duration for main lines? **150 pounds per square inch / 2 hours.**

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10. Before testing, the line should be **thrust blocked / backfilled / flushed / all air removed**.

11. During a pressure test, the pressure continues to bleed down slowly, you probably have **air** in the line.

12. To assist in pressure testing, bleed valves should be placed at the **highest point** in the line.

13. If a stop and waste valve is designed to be used at the curb on every service installation, the arrow on the valve should point **toward** the building.

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SECTION III ASSIGNMENT SHEETS

Define the terms:

Level

Parallel with the plane of the horizon / horizontal, also, a device for establishing a horizontal line or plane by means of a bubble in a liquid.

Offset

The distance measured from a design feature to the off-set stake line / stakes set back out of construction process / so staking is not destroyed.

Percentage of Grade

The amount of slope of a pipe from one point to another / this slope can be expressed as a rate per foot.

Plumb

Straight up or down / vertical / also, exactly vertical or true.

Rate Per Foot

The actual amount of vertical rise or fall in the horizontal distance of one foot.

Reference Point

A point of know alignment and elevation / usually used to describe another point or location.

Square

At right angles / also forming a right angle / also having four equal sides and forming four right angles.

Station

A horizontal distance of 100 feet or an actual location on a project center or baseline / also to assign to or set in a station or position.

Story Pole

A job constructed piece of lumber used to indicate various elevations or layouts.

Slope Ratio

A horizontal to vertical relationship with the horizontal expressed first and the vertical always expressed as one.

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Convert the following expressions from U.S. Standard expressions to decimal feet:

1. 1/4" = .02
2. 5 7/8" = .49
3. 4 7/8" = .40
4. 8 5/8" = .72
5. 16 1/2" = 1.37
6. 12 3/4" = 1.06
7. 28 3/4" = 2.39
8. 10 1/2" = .87
9. 14 3/8" = 1.20

Give the new station after taking the following measurements from 0+00.00 station.

10. What is the station designation of a point 112.00 feet ahead of 0+ 00?
    = STA . 1 + 12.00
11. What is the station designation of a point 2341.78 feet ahead of 0+ 00?
    = STA. 23 + 41.78
12. What is the station designation of a point 47.21 feet ahead of 0+ 00?
    = STA. 0 + 47.21

Give the new station after taking the following measurements from 16 + 32.29 station.

13. What is the station designation of a point 112.00 feet behind 16 + 32.29?
    = STA. 15 + 20.29
14. What is the station designation of a point 2341.78 feet behind 16 + 32.29?
    = STA. - 7 + 09.49
15. What is the station designation of a point 47.21 feet ahead 16 + 32.29?
    = STA. 16 + 79.50

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Calculate the distance between the following stations:

16. Sta. 12+50 to Sta. 15+50 **= 300'**

17. Sta. 13+56 to Sta. 18+49 **= 493'**

18. Sta. 10+29.95 to Sta. 11+13.69 **= 83.74'**

19. Sta. 133+45.29 to Sta. 138+17.21 **= 471.92'**

20. Sta. 0+51.28 to Sta. 5+36.16 **= 484.88'**

Calculate the elevation differences between the following measurements or elevations:

21. Point #1 measurement = 12.26 Point #2 measurement = 4.32 **= 7.94'**

22. Point #1 elevation = 138.63 Point #2 elevation = 143.16 **= 4.53'**

Calculate the following elevation changes:

23. 3.0% for 150' **= 4.50'**

24. 1.5% for 187' **= 2.805 = 2.81'**

25. 0.005'/ft. for 133' **= 0.665 = 0.67'**

26. 0.0075 '/ft. for 187.32' **= 1.1049 = 1.40'**

27 - 1.84% from Sta. 10+50 to Sta. 11+86 **= -2.5024 = -2.50'**

Match the following reference symbols to corresponding definition.

28.

(15)	**Hub = 127.34**	reference elevation
C 6^4	(15)	horizontal distance
hub = 127.34	**STA. 12~ STA. 12 + 00.00**	1200' feet from 0+00
sta. 12~	**C 6^4**	vertical distance

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Calculate the elevation of the indicated station by adding or subtracting the elevation change from the starting elevation. Be careful with ahead and back station questions.

	Station	Elevation	Slope	Station	Elevation
29.	Sta. 11+27	675.04	+1.27%	Sta. 13 +15 =	**677.43**
30.	Sta. 25+31.18	130.92	-2.43%	Sta. 27+32.16 =	**126.04**
31.	Sta. 42+39.42	43.96	-1.14%	Sta. 39+39.56 =	**47.38**
32.	Sta. 15+86.23	1215.79	+0.0031'/ft.	Sta. 12+18.89 =	**1214.65**
33.	Sta. 437+21.15	764.71	-0.055'/ft.	Sta. 442+19.23 =	**737.32**

The following assignment sheets are designed for a field exercise. Your instructor will give you further instruction and proper procedures. Information in the manual will help you complete this exercise.

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SECTION IV ASSIGNMENT SHEETS

Answer the following sanitary sewer questions:

1. What is the usual allowable tolerance for every joint of sanitary sewer pipe?

   Common requirements for 8" pipe range 0.02 ± 0.03 per joint of pipe.

2. What can happen if a sewer line is installed at too great a gradient?

   The liquids will separate from the solids and create blockages.

3. Name four common pipe types used in sanitary sewer construction.

   Vitrified clay.
   Polyvinyl chloride (PVC).
   Reinforced concrete pipe. (RCP)
   Ductile iron pipe (DIP).

4. Why is it important to handle clay pipe carefully?

   It is a rigid pipe that breaks easily.

5. List two types of vitrified clay bell ends.

   Bell ends formed of clay and plastic bell ends which are fused onto the pipe / both use rubber gaskets to form the seal.

6. What is the length of clay pipe joints?

   Two to six feet.

7. What are the diameters and lengths of manufactured PVC pipe?

   From four inches to twenty four inches and in twenty foot / thirteen foot and twelve foot six inches in length.

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8. Name two different types of material that are used to join PVC pipe joints and fittings.

PVC pipe joints and fittings are joined using rubber gaskets push-on type joints and/or solvent cement joints.

9. When is a reinforced concrete pipe used in a sanitary sewer system?

When the installation requires an exceptionally deep bury.

10. What are the diameters and lengths of RCP?

Twenty four inches to one hundred eight inches in diameter and in four foot, eight foot and twelve foot lengths.

11. What is the length of ductile iron pipe joints?

Eighteen and twenty foot lengths.

12. How much bedding material is normally placed under a pipe, if it is required?

Four to six inches of bedding.

13. What should you do to bedding in order to give satisfactory support to the pipe?

Bedding must be compacted to provide satisfactory support for the pipe.

14. Debris between the **gasket** and **spigot** will cause a leak.

15. How far do you push the spigot into the bell end of a pipe?

Push spigot into bell until the reference line reaches the bell or until the line disappears.

16. What has to be done to the haunching area in order to keep a pipe from being deformed?

This area requires compaction to required density to prevent deformation of pipe.

17. Why would you use a T-bar?

May be used to compact under the pipe and bells holes.

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18. What is the maximum depth of a lift of haunching material?

Depending on pipe size, haunching material should be added in four inch lifts.

19. How far apart are manholes placed? Why?

Two hundred to four hundred feet apart / to allow for direction changes and access for maintenance.

20. When are drop inlets installed?

When the line has an elevation difference of two feet or more between the inflow line and springline of the outflow pipe.

21. Why are cleanouts constructed at a 45 degree angle?

To allow for the easy insertion of snake or flush hose.

22. What is the purpose of a lateral?

A lateral transfers waste from a residence or business to the main line.

23. What is the required grade for lateral pipe installation?

$^1/_8$" / foot min. to $^1/_2$" /foot max.

24. What is the most common way to repair gravity flow pipe?

Flexible rubber couplings called either fernco or mission couplings.

25. When repairing concrete pipe 15" in diameter or larger, what part of the bell end is removed on the existing pipe?

Top half of bell on "existing pipe".

26. What is the purpose of a low pressure sewer test?

The rate of air loss is intended to indicate the presence or absence of pipe damage and proper installation.

27. Low pressure air tests are used on pipes from **four** inches to **twenty four** inches in diameter.

28. What should you do to a test plug after it has been installed?

Must be braced.

29. Why are inflatable test plugs dangerous?

When the pressure test is applied, an 8" plug will have approximately 250 pounds of force, with only 5 PSI of test pressure.

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30. When is it safe to enter a manhole or remove plugs?

When you are absolutely sure that all the air pressure has been completely released.

31. Why is it important for an invert to be shaped as smoothly and evenly as possible?

Any change in direction can create blockages, invert must be smooth as possible.

Answer the following storm drain questions:

32. Name five parts of a storm drain system.

Catch basins
Inlets
Manholes
Lead pipes
Main lines

33. What are the normal slope tolerances for storm drain pipe joints?

Range from 0.02 ft/ft to 0.05 ft/ft. 0.02 ft/ft for eight foot concrete pipe joint. 0.05 ft/ft for a twenty foot corrugated metal pipe joint.

34. What are the three major storm drain pipe types?

Reinforced Concrete Pipe (RCP)
Corrugated Metal Pipe (CMP)
Corrugated Polyethylene Pipe (CPP)

35. What are the two types of rubber gaskets used in RCP?

Flat compression type rubber gaskets.
O-Ring type rubber gaskets.

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36. Name three basic coupling designs for RCP.

Bell and spigot mortar joint.
Bell and spigot O-ring joint.
Tongue and groove joint with mastic sealer.

37. Why is proper bedding and haunching of CMP important?

Because CMP is flexible, bedding and haunching of the pipe is very important.

Answer the following subdrain questions:

38. What kind of pipe is used during subdrain installations?

Perforated polyvinyl chloride, perforated corrugated metal pipe, perforated corrugated polyethylene pipe.

39. What lengths of PVC pipe are used for subdrain installations?

12 ½ to 20 ft. joint lengths.

40. What is the primary use for CMP and CPP?

Ground water collection systems.

41. How much crushed, washed gravel is placed over perforated CPP?

Minimum of twelve inches.

42. Why is the crushed, washed gravel placed over the CPP?

To prevent siltation and clogging of the perforations.

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Trench Protection and Principles of Pipe Laying

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LIUNA INNOVATION AT WORK

ACKNOWLEDGEMENTS

Laborers-AGC Education and Training Fund would like to thank the following people and organizations who were instrumental in the development of this training manual and curriculum.

The curriculum review committee:

Archie Gorman -	Training Instructor	The Francis L. Greenfield Laborers & Construction Industries Institute
Ron Hadden -	Training Instructor	Illinois Laborers and Contractors Training Fund
Glen Murphy -	Training Instructor	Ohio Laborers Training & Upgrading Trust Fund
Arnie Stoeberl -	Training Instructor	Kentucky Laborers Training Trust Fund
Robert Williams -	Training Director	Laborers District Council Training Fund of Baltimore & Vicinity

A special thanks is extended to ***Arnie Stoeberl*** of the Kentucky Laborers Training Trust Fund for the long hours he spent compiling the information included in this manual.

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SECTION I: TRENCHING AND EXCAVATION SAFETY

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Trainee Objectives

Define the terms:

Benching	Wales	Slope Ratio
Competent Person	Sheeting	Trench
Cross Braces	Shield	Uprights
Excavation	Sloping	Hazardous Atmosphere

Describe the soil characteristics and identify the sloping requirements for:

Type A Soil
Type B Soil
Type C Soil

Describe three types of protective systems

Identify who is required to inspect an excavation and the frequency of inspections.

Describe three warning signs of a previous excavation or an unmarked existing utility.

Describe three types of hazardous atmospheres and their physical descriptions.

Describe permit required confined space legislation.

Describe techniques to prevent back injuries

Competently install:

Timber tight sheet shoring
Shoring with screw jack bracing
Shoring with hydraulic shoring

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TERMS AND DEFINITIONS

The terms in this section are defined the same as in the Occupational Safety and Health Construction Standards § 1926.650.

Benching: (Benching system) is a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Cross Braces: The horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Excavation: Any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Hazardous Atmosphere: An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, and may cause death, illness, or injury.

Sheeting: The members of a shoring system that retains the earth in position and in turn are supported by other members of the shoring system.

Shield: (Shield system) is a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either pre-manufactured or job-built in accordance with § 1926.652 (c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Slope Ratio: A horizontal to vertical relationship with the horizontal expressed first and the vertical always expressed as one.

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Sloping: (Sloping system) is a method of protecting employees from cave-ins by excavating to form sides that are inclined away from the excavation. The angle of incline varies with differences in soil type, environmental conditions of exposure, and application of surcharge loads.

Trench: (Trench excavation) is a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6m). If the excavation is wider than 15 feet, a structure can be built inside the excavation so that 15 feet or less exists from the side of the structure to the edge of the excavation. This can also be considered a trench.

Uprights: The vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales: The horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

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TERM DEFINITIONS FOR APPENDIX A

Cemented Soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate. A hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive Soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, and organic clay.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular Soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered System means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Submerged Soil means soil which is underwater or is free seeping.

SOIL CHARACTERISTICS FOR TYPE A, B, AND C SOILS (AS DEFINED IN APPENDIX A TO SUBPART P OF PART 1926)

Type A Soil means:

Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam, and in some cases, silty clay loam and sandy clay loam. Cemented soils, such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

(i) The soil is fissured; or
(ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
(iii) The soil has been previously disturbed; or
(iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4:1) or greater; or
(v) The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soil means:

(i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf, but less than 1.5 tsf; or
(ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam, and in some cases, silty clay loam, and sandy clay loam.
(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.

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(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or
(v) Dry rock that is not stable; or
(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4:1), but only if the material would otherwise be classified as Type B.

Type C Soil means:

(i) Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
(ii) Granular soils including gravel, sand, and loamy sand; or
(iii) Submerged soil or soil from which water is freely seeping; or
(iv) Submerged rock that is not stable; or
(v) Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4:1) or steeper.

Unconfined Compressive Strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

WORKER PROTECTIVE SYSTEMS

As with all construction work, it is important that you understand that you are ultimately responsible for your own safety. The revised OSHA Construction Standards 1926.650, 1926.651, and 1926.652, enacted in 1991, deal specifically with trenching and excavation operations.

Most of the worker protection regulations will be covered in this section, but you are encouraged to study the regulations included in Appendix B of this manual. Ask your instructor if you have questions concerning the regulations.

Worker protection for excavations and trenches can take two forms. The first form is a protective structure system, such as a trench shield or shoring structure. Various types of protective systems and bracing are illustrated in Figures 1-1 through 1-5.

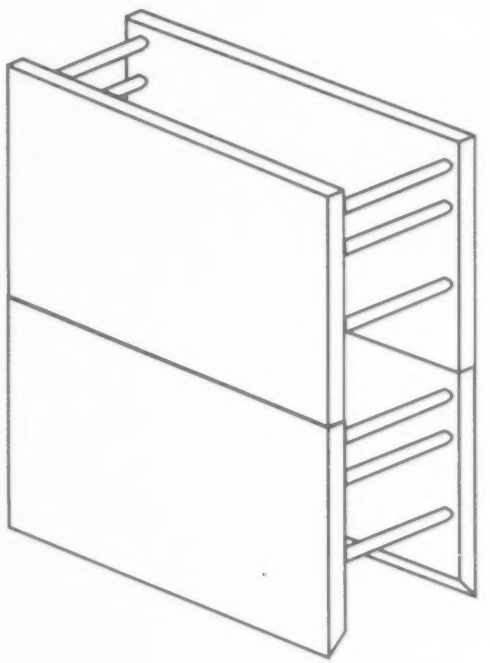

Figure 1-1
Trench Shield

Usually commercially manufactured, a trench shield will be pulled along by the excavator as the excavation continues.

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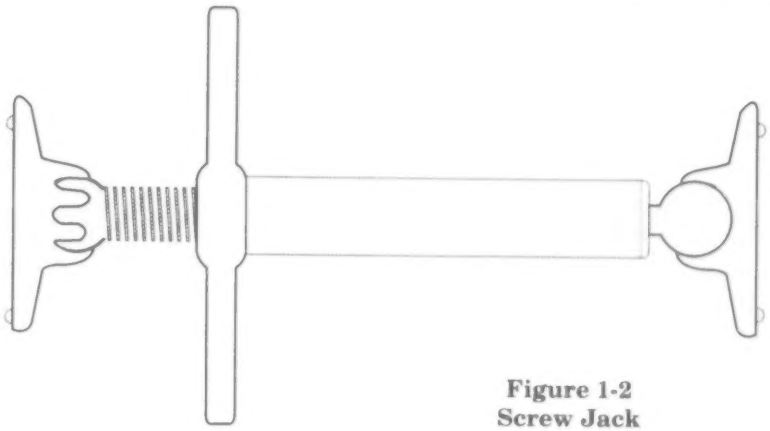

Figure 1-2
Screw Jack

Screw jacks can be used for cross bracing tight sheet or skeleton shoring systems.

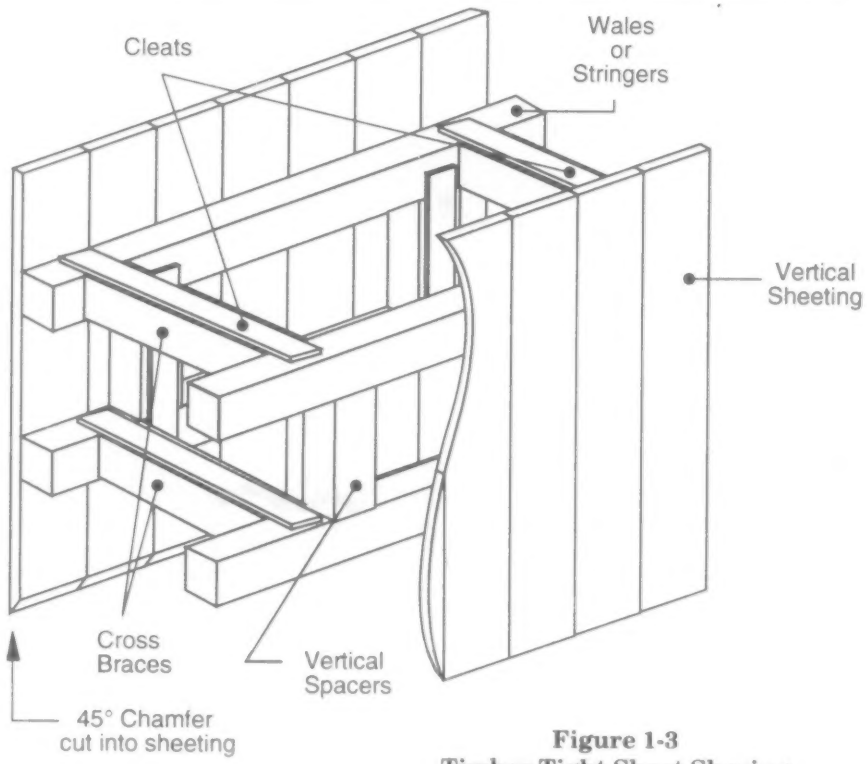

Figure 1-3
Timber Tight Sheet Shoring

Tight sheet shoring is usually constructed for excavations that are close to other structures or for excavations of longer duration.

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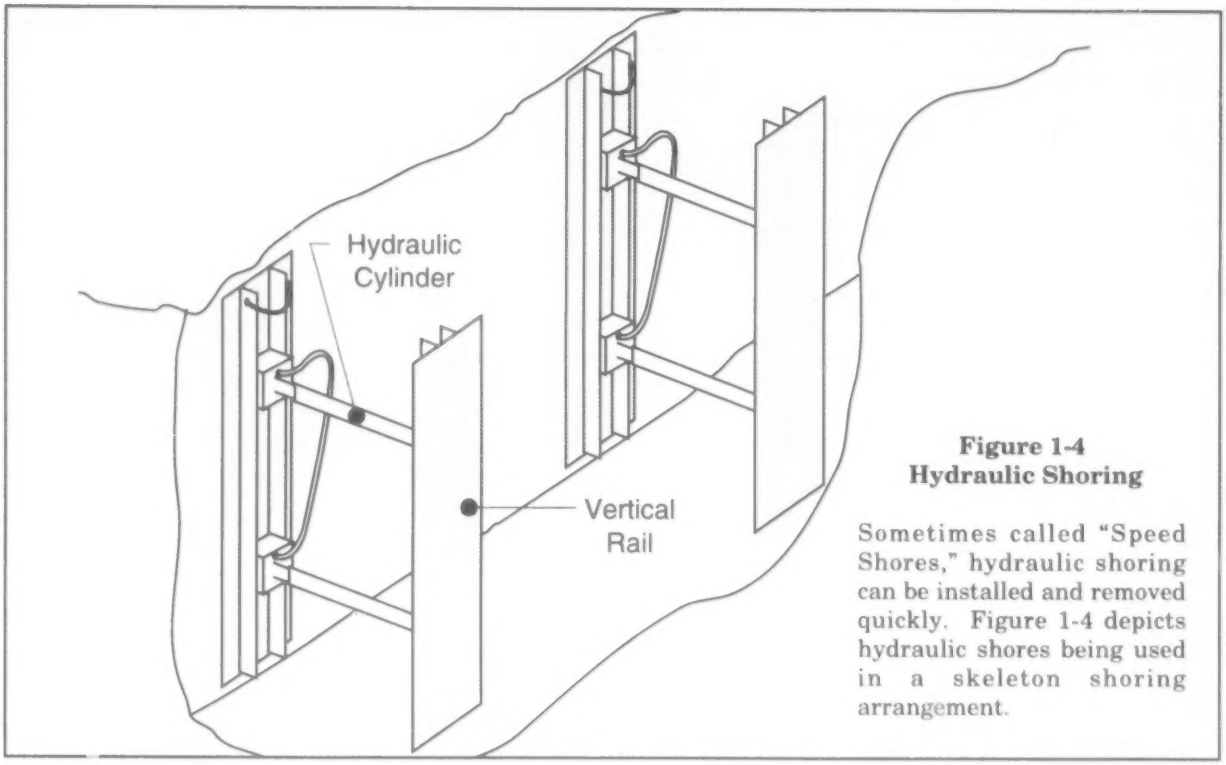

Figure 1-4
Hydraulic Shoring

Sometimes called "Speed Shores," hydraulic shoring can be installed and removed quickly. Figure 1-4 depicts hydraulic shores being used in a skeleton shoring arrangement.

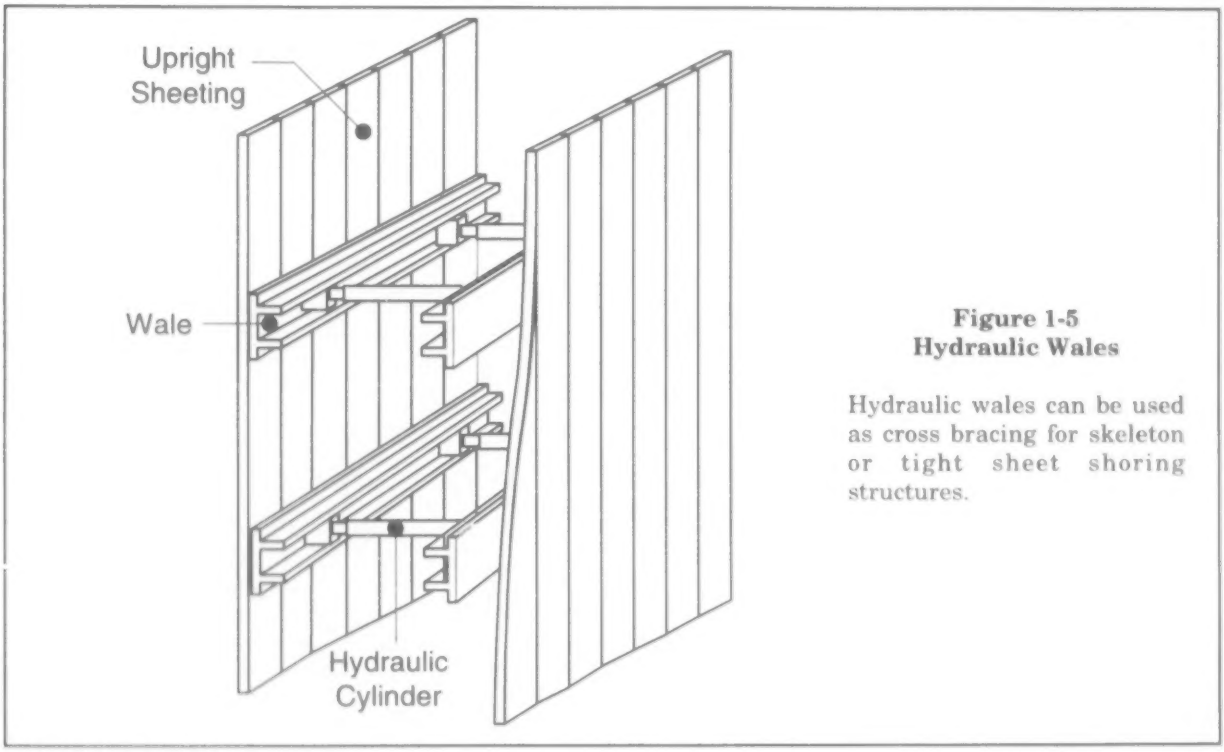

Figure 1-5
Hydraulic Wales

Hydraulic wales can be used as cross bracing for skeleton or tight sheet shoring structures.

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The second type of protective system involves sloping the sides of a trench or excavation enough to prevent material from sliding or caving onto the workers.

Due to the additional costs and reduced production while using a shoring structure, most contractors will attempt to protect the workers by sloping the sides of an excavation or trench. If this sloping is not adequate, the possibility of workers being injured or killed in a trench or excavation increases.

The OSHA regulations provide contractors with for methods of complying with the sloping requirements.

Option (1) Section 1926.652 paragraph (b) (1)

Excavations shall be sloped at an angle not steeper than 1 1/2:1. A 1 1/2:1 ratio is the slope that most material is expected to stand unsupported for an indefinite amount of time.

Option (2) Section 1926.652 paragraph (b) (2)

The contractor using this option is choosing to make a determination of the slope and configuration using Appendices A and B from section 1926. This means that the contractor is going to base the actual slope required on the soil classification (i.e., Stable Rock, Type A, B, or C). Appendix A states "the basis of classification shall be based on the results of at least one (1) visual and at least one (1) manual analysis. Such analyses shall be conducted by a competent person using tests described in paragraph (d)."

The visual test is conducted to determine quality information regarding the excavation site in general, for example; the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated materials. What is acceptable as a visual test is further defined in Appendix A (d)(1) (i) to (d)(2) (vii).

Table 1-1
Maximum Allowable Slopes

Soil or Rock Type	Maximum Allowable Slopes for Excavations Less Than 20 Feet Deep.(1)
Stable Rock	Vertical (90°)
Type A (2)	3/4:1
Type B	1:1
Type C	1 1/2:1

TABLE 1-1 NOTES

(1) Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

(2) A short-term (excavation open 24 hours or less) maximum allowable slope of 1/2:1 is allowed in excavations in Type A soil that are 12 feet or less in depth. Short-term maximum slopes for excavations greater than 12 feet in depth shall be 3/4:1.

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The manual test is conducted to determine the quantity, as well as the quality properties of the soil and in order to classify the soil properly. What is acceptable for manual tests is further defined in Appendix (A) (d)(2)(i) to (d)(2)(v).

To summarize the use of this option, the contractor must have a competent person perform a visual and manual test on the material in accordance with the requirements in Appendix A and B. Once the classification of the material has been determined, the excavation cannot be sloped steeper than the allowable slope for the material type (Table 1-1).

Option (3) Section 1926.652 paragraph (b) (3)

The contractor choosing this option is going to design the slopes using "other tabulated data." Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts. The tabulated data must be in written form and contain information, such as factors affecting the sloping or benching system selected, identification of the limits of the data including the size and configuration of slopes to be constructed, all explanations that are necessary to assist the user in making the correct selection of which protective system is needed.

The final requirement for this option is one (1) copy of the tabulated data with the stamp of the professional engineer that approved the data to be kept on the job site during the construction of these systems. (Copies must be kept after the construction has ended and made available to the Secretary at their request.)

Option (4) Section 1926.652 paragraph (b) (4)

Option 4 states that the design for the protective system be provided by a registered professional engineer. This option is left to all contractors who will not be using options 1 through 3. This option also states that "designs shall be in written form and include at least; the size of the slopes that were determined to be safe, the configurations that were determined to be safe, the identity of the registered professional engineer approving the design, and that a copy of the design be kept on the job site during the construction of these systems. (Copies must be kept after the construction has ended and made available to the Secretary at their request.)

EXCAVATIONS: INSPECTIONS AND FREQUENCY

Section 1926.651 paragraph (k) addresses the topic of inspections. It explicitly states that DAILY inspections of excavations, adjacent areas, and protective systems by a competent person shall be made. This shall be done prior to the start of work and as needed throughout the shift. Inspections by a competent person must also be conducted after every rainstorm or other hazard-increasing occurrence.

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WARNING SIGNS FOR PREVIOUS EXCAVATIONS AND/OR UNDERGROUND UTILITIES

When a trench is excavated across or alongside a previous excavation, the chance of the trench walls sliding or caving is greatly increased. You as a pipelayer should always be aware of the type of material that is being excavated and watch for any change. A change in the material will often affect the way the material is standing, either for better or for worse, or it may signal that you are close to a previous excavation.

One of the sure signals of a previous excavation is debris. Garbage will not show up in undisturbed earth, if the excavator suddenly brings out pieces of paper, soda cans, etc., stop or slow down the excavator until you can identify the area with the debris. Once you have located the source of the debris, excavate slowly or use a shovel to check for unmarked utilities in that area.

Another sign of a previous excavation is a sudden change or mixed up soil. For example, if topsoil is exposed below a layer of other material, it could indicate that the area had been previously disturbed.

Utility companies will often bury a colored warning tape about a foot above the utility. Most notably, the Electric and Phone utilities will follow this procedure. Colored red or yellow, the tape is about 4" wide with cautions printed in black on the top. If you notice a piece of this warning tape in the excavation, stop the excavator and locate the utility below the warning tape with a shovel.

Whenever the excavation enters a previously excavated area, work with the excavator operator to ensure that the sides are sloped enough to prevent sliding or cave-ins.

HAZARDOUS ATMOSPHERES

Pipelayers should always be aware of the possibility of hazardous atmospheres and where they are likely to occur. Every year, pipelayers die due to failure to take precautions against the presence of toxic gases or the lack of oxygen.

Any confined space is a likely place for a hazardous atmosphere; a storm drain or sewer manhole are perfect examples. The hazardous atmospheres can occur as a by-product of sewage. Diesel equipment operating close to the work area can also create hazardous fumes. Some hazardous atmospheres likely to occur in manholes or trenches include:

- Oxygen deficient
- Hydrogen sulfide
- Methane
- Carbon monoxide
- Diesel engines
- Nitrous oxides

The hazardous atmospheres are listed in Table 1-2. Oxygen deficient atmospheres are likely to occur when other gases (that are either heavier or lighter than air) displace the oxygen in a confined space.

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Hydrogen Sulfide (H_2S) is one of the most poisonous gases known. In low concentrations its distinctive "rotten egg" odor is noticeable, but in higher concentrations the sense of smell will be quickly paralyzed by the action of the gas on the respiratory center and cannot be relied on for warning. This gas is heavier than air and can be expected to collect in low areas. When inhaled in a sufficiently high concentration, immediate asphyxiation and death can result. This gas can be formed from the decomposition of organic matter, such as sewage or garbage.

Methane (CH_4) is also called "marsh gas" and can be formed by the decomposition of organic matter in the presence of water and the absence of air or oxygen. Methane is odorless, colorless, tasteless, and flammable. This gas is considerably lighter than air and can be expected to collect in higher locations. Although it has no direct effect on the respiratory system, it may displace oxygen and create an oxygen deficiency.

Carbon Monoxide (CO) is colorless, odorless, tasteless, and flammable, and is usually produced as a by-product of incomplete combustion, such as the exhaust of gas or diesel engines. Carbon Monoxide will produce symptoms of poisoning even when inhaled in low quantities. Those symptoms include headache, heart palpitation, staggering, confusion, nausea, and unconsciousness. The effect of high concentrations may be so sudden that one has little or no warning before collapsing.

Table 1-2: Common Hazardous Atmospheres

Hazardous Atmosphere	Likely Source	Physical Description
Oxygen deficient	Displacement of other gases	Less than 19.5 % Oxygen is hazardous
Hydrogen sulfide	By-product of sewage when it breaks down and rots	Odor like rotten eggs, flammable, and is heavier than air. Cannot smell in higher concentrations.
Methane	By-product of the decomposition of sewage	Colorless, odorless, tasteless, flammable, and is lighter than air
Carbon monoxide	Gas or diesel engines	Colorless, odorless, tasteless
Nitrous oxides	Diesel engines	Colorless, odorless, tasteless, and is heavier than air

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Nitrous Oxides (NO) (NO_2) (NO_3) are colorless, odorless, tasteless, and heavier than air. The oxides of nitrogen are likely to occur as a result of diesel combustion. They are colorless in lower concentrations and reddish-brown in higher concentrations, odorless, and tasteless. Exposure to concentrations of Nitrogen Dioxide may only display signs of mild bronchial irritation(1) followed by a five- to twelve-hour symptom-free period. Subsequently, the onset of acute pulmonary edema(2) can occur suddenly. Being heavier than air, these gases can be expected to collect in the lower portions of a confined area.

Hazardous atmospheres are a very real danger for workers involved in utility construction work. There is a simple way to avoid these dangers; always ventilate and test the air quality in an enclosed area, and do not enter an area that has not been tested or adequately ventilated.

PERMIT REQUIRED CONFINED SPACES

The Occupational Safety and Health Administration (OSHA) has published a final confined space ruling, January 14, 1993. Ninety days from this date, 29 CFR 1910.146 will come into affect. It is recommended that the provisions from this standard are used to protect exposed workers from confined space hazards. OSHA estimates that if this standard is followed after it comes into affect April 15, 1993, appoximately 53 deaths can be avoided each year.

The following information is a partial summary of the standards. Consult the standard for actual wording and interpretation. Some states must revise their standards to exceed or match OSHA permit required standards.

Permit Systems

The confined space that you enter may require a permit. A permit system is the employers written procedure for preparing or issuing entry permits. The permit may require any or all of the following:

- Rescue service.
- Retrieval system equipment, such as a rescue line, body harness, wristlets, and a lifting device.
- Testing.

Employers must check the workplace to see if any spaces are confined spaces (Figure 1-6). The definition of a confined space is:

- A large enough space that can be entered to work in.
- Has limited or restricted means of entry or exit.
- Is not designed for continuous employee occupancy.

(1) Bronchial irritation would be similar to symptoms experienced from a cold or flu.
(2) Acute pulmonary edema would be similar to symptoms experienced from pneumonia.

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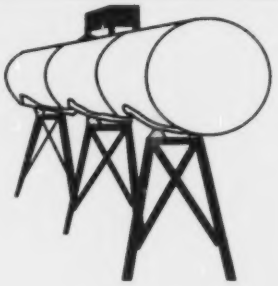
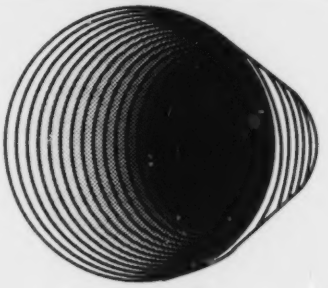
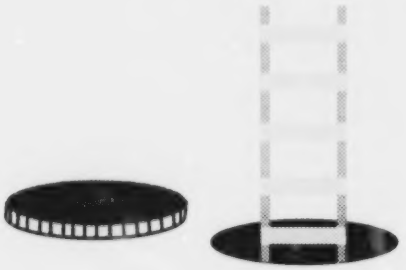


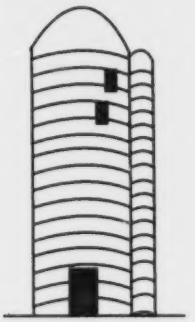
Storage Tank



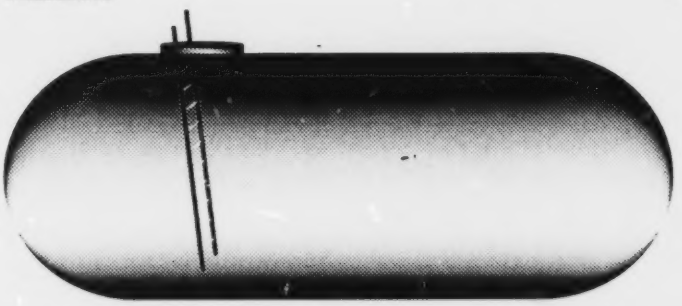
Pipeline



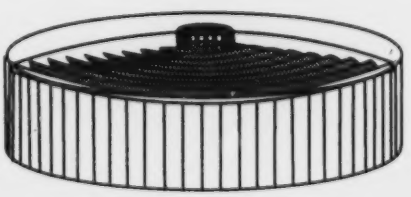
Manhole



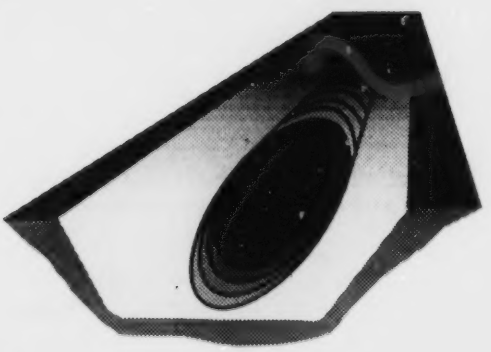
Silo



Vessel



Digester



Trench

Figure 1-6
Examples of Confined Spaces

A confined space may have a hazardous atmosphere. A hazardous atmosphere can expose workers to risk of death, permanent or partial impairment that prevents the worker from escaping injury, or acute illness. A hazardous atmosphere may contain:

- Flammable gas, vapor, or mist greater than 10% of its lower flammable limit (LFL).
- Airborne combustible dust that is greater than or equal to its LFL. Usually this condition occurs when you cannot see greater than 5 feet.
- Oxygen concentration less than 19.5% or greater than 23.5%.
- Any substance in the confined space that exceeds its permissible exposure limit.
- Any other condition within the confined space that is immediately dangerous to life or health.

A non-permit confined space is a space that does not contain any hazard that can cause death or serious physical harm. A permit is needed in a confined space when the space:

- Contains or *has potential* to contain a hazardous atmosphere.
- Contains a material that can engulf the worker.
- Becomes smaller and smaller. (Workers can be trapped or can choke to death.)
- Contains other serious safety and health hazards.

An employer must have a permit system in place if any of the above conditions exist. If conditions change, a permit required confined space may be reclassified as a non-permit confined space. The space may be changed back to a permit confined space if hazardous conditions return.

If the workplace contains confined spaces requiring permits, the employer must inform their employees by posting danger signs or other equally effective communications. A sign reading "DANGER - PERMIT REQUIRED CONFINED SPACE, DO NOT ENTER," would be satisfactory. Even if the employer decides that the confined space will not be entered, the employer has to take effective measures to prevent employees from entering the permit space. If the employer decides that the employees will enter the permit space, the employer must have a written permit space entry program that meets OSHA requirements.

Employers may not have to follow confined space entry permit requirements if they find the following conditions:

- A potential, rather than actual, hazardous atmosphere exists.

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- Air ventilation makes the space safe for entry.
- Monitoring and inspection data back up the above two conditions.
- Proper precautions are taken in accordance with OSHA standards if the space must be entered to gather data that shows a permit is not required.
- Air ventilation, monitoring, inspection, and hazardous atmosphere information are all made available to the employee who must enter the space.

Forced Air Ventilation Requirements

What are some good work practices, when using equipment, such as fans (Figure 1-7), air movers, or blowers during continuous forced air ventilation? Here are some requirements:

- Never enter the space until the forced air eliminates the hazard.
- The forced air must ventilate the immediate area where you are working.
- The forced air must come from a clean source, and it should not increase the hazard in the space.
- The ventilated space must be tested periodically.

Keep in mind that forced air ventilation by itself, may not completely remove the hazardous atmosphere. That is why the employer must provide documentation that shows no hazards exist inside the permit space.

Permit Spaces that Become Hazardous

What if the space becomes hazardous during entry? OSHA lists important requirements:

- Leave the space immediately.
- The cause of the hazardous atmosphere is found before re-entry.
- Protective measures are taken before re-entry.

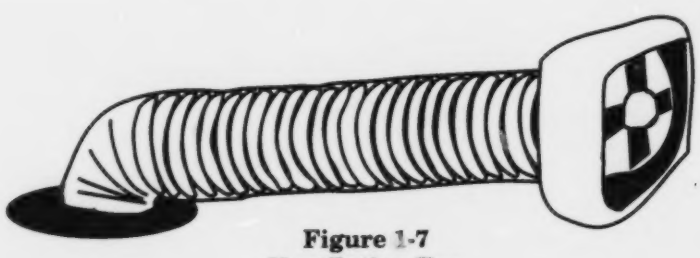

Figure 1-7
Ventilation Fan

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- The employer provides written certification that the space is safe for entry again. The employer must make this certification available to you before you enter the space. The certificate must have the date, space location, and signature of the person who has provided the certificate.

Permit Required Confined Space Program

An employer must follow special conditions if a permit-required confined space program is in place. Employers may need to follow any or all of these conditions. What are the responsibilities of the employer? They must:

- Take measures to prevent unauthorized entry into the space.
- Identify the hazards before employees enter the space.
- Specify acceptable entry procedures.
- Isolate the space.
- Purge, inert, flush, or ventilate the permit space.
- Test and monitor equipment.
- Lighting equipment.
- Provide ventilating equipment.
- Provide the communications equipment.
- Provide employees with personal protective equipment, such as Self-Contained Breathing Apparatus (SCBA) (Figure 1-8) if engineering or work practice controls do not give employees adequate protection.

Figure 1-8
Self- Contained Breathing Apparatus

- Protect entrants from outside hazards.
- Provide ongoing verification that the space can be entered.
- Provide properly maintained equipment.
- Train workers on the proper use of equipment.

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- Barriers and shields.
- Equipment (e.g., ladders) needed for exit or entry into the space.
- Rescue and emergency equipment.
- Perform pre-entry tests.
- Provide at least one attendant outside the permit space during entry operations. (Attendants can monitor more than one space as long as they can perform their duties effectively for each permit space that they monitor.)
- If multiple spaces are monitored, the employer must allow the attendant to respond to an emergency without taking away from their responsibilities in the other spaces.
- Designate the workers who have active roles in the space. You would be a designated worker if you were an authorized entrant, attendant, entry supervisor, test person, or monitor. The employer must identify your duties and train you, if you are a designated worker.
- Develop and implement procedures for getting rescue and emergency services.
- Develop and implement a system for preparing, issuing, using, and canceling entry permits.
- When workers from more than one company are in the space, their employers must coordinate entry operations.
- Close off the space and cancel the permit after entry is completed.
- Review and revise the entry program to correct problems.
- Review and revise the entry program within one year after entry.

Testing a Permit Space

Before you enter a permit space, it must be tested. If the space is a "continuous system" (e.g., a sewer), pre-entry testing must be done by the employer before you enter the sewer. If you are authorized to enter the sewer after testing, your employer must continuously monitor the area where you are working.

There are a number of air monitoring devices on the market that are able to provide continuous air monitoring. This common sense practice has become law because dangerous gases can travel great distances along a sewer line and gases cannot be isolated from the area where you are working.

When testing for atmospheric hazards, you must test in a particular order. First, test for oxygen, then combustible gases and vapors, then for toxic gases and vapors (Figure 1-9).

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Figure 1-9
Worker Tests Oxygen, Combustibles, then Toxic Gases

Permit Requirements

A permit is a prepared document that must be completed before entry into the space can be authorized. Before entry can begin, the entry supervisor named on the permit must sign the permit. The permit has to be posted at the entrance or in some other manner, so that if you enter the space, you know all the preparations have taken place. The permit has to be made available to all authorized entrants.

When you have to work in a permit space, the job you need to do must be noted on the entry permit. Whatever work you need to complete must be done before the time on the permit expires.

The entry supervisor must end the entry and cancel the permit after work listed on the permit has been completed or a condition comes up that is not allowed on the permit. The employer has to keep a canceled entry permit for at least one year, so that the entry program can be reviewed.

The following information must be on a permit:

- The permit space that has to be entered.
- The purpose of the entry.
- The date and duration of the entry permit.
- Some way that the attendant can quickly tell which authorized persons are in the confined space. For example, the entrant's name, rosters, or tracking systems.
- The name of the person who is currently serving as attendant.
- The name of the person who is currently serving as entry supervisor, with a space for the signature or initials of the entry supervisor who originally authorized the entry.
- The hazards inside the confined space.
- The measures used to isolate the space and to eliminate or control the hazards in the space before it is entered.

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- Acceptable entry conditions.
- The result of the first test on the space and other tests later on.
- Rescue and emergency services that can be called.
- Communication procedures used between entrants and attendants.
- Any equipment that is provided in accordance with OSHA regulations.
- Any special information that employees need to know.
- Any additional permits, such as hot work permits.

Employer Training

An employer must provide training so that workers have enough knowledge and skills to perform their duties safely according to OSHA permit space legislation. If your work is related to permit spaces, the employer has to train you before your first work assignment, or before there is any change in your duties. If employers change permit space operations, new hazards might surface. If you have never had any training for this newest hazard, your employer must give you this training. The employer must give you further training if there are changes in the permit procedures or if the employer finds inadequacies in your knowledge of the procedures. New or revised procedures must be introduced, and the training must establish your proficiency.

Your employer must certify that the conditions just mentioned have been met. The certification has to have your name, signatures or initials of the trainers, and dates of training. The certification has to be available for inspection by employees or an authorized representative, such as your field representative.

Entrant Information

The employer has to ensure that you know the hazards you will face during entry, including information on the form of the hazard, signs or symptoms, and consequences of the exposure. The employer must show you how to use equipment properly. Employers have to communicate with the attendant, so that the attendant can monitor the status of the entrants and evacuate the space according to OSHA regulations. If you are a permit entrant and you discover signs or symptoms of dangerous exposure, or prohibited conditions, you must alert the attendant. As an entrant, you must exit the permit space as quickly as possible whenever:

- An order to evacuate is given.
- You recognize any warning signs or symptoms of dangerous exposure.
- You find a prohibited condition.
- An evacuation alarm sounds.

Attendant Duties

An employer has to make sure you know the hazards during entry in the space, and the possible behavioral effects of entrants. As an attendant, you would

have to stay outside the permit space and keep an accurate count of authorized entrants, until you are replaced by another attendant. You can enter a permit space to rescue other workers, only if you have been trained and equipped for rescue operations and the permit entry program allows you to enter the space. Another attendant has to stay outside the space, if you enter the space for rescue purposes. As an attendant, you would have to communicate with entrants to monitor their status and evacuate them, if necessary. Attendants monitor activities inside and outside the space and evacuate the space immediately if:

- You detect a prohibited condition.
- You detect behavioral effects of hazardous exposure.
- You detect a dangerous situation outside the space that could endanger workers inside the space.
- You cannot effectively and safely perform your duties.

Call rescue and emergency services when you find that entrants need help to escape a hazardous permit space.

If an unauthorized person approaches or enters a permit space, tell them they must stay away from the space, and advise them to exit immediately if they have entered the space. Tell authorized entrants and the entry supervisor that an unauthorized entrant is inside the space. An attendant can perform non-entry rescues that are specified by the employer's rescue procedure.

Rescue and Emergency Service Requirements

Your employer has to follow certain requirements if you are a member of a rescue team. They must:

- Train you to use personal protective equipment and rescue equipment for permit space rescues.
- Train you to perform assigned rescue duties.
- Give you the same training as authorized entrants.
- Allow you to practice rescue duties by removing dummies, manikins, or actual persons from a simulated or actual permit space, at least every 12 months.
- Give you training in basic First Aid and CPR.
- Make sure one member of your rescue team has current First Aid and CPR certification.

Retrieval systems can be used to help you with non-entry rescue while an entrant is within an entry space, unless the retrieval system increases the overall risk of entry or rescue of the entrant.

When retrieval systems are used, each entrant has to wear a chest or full body harness with a line attached to a point near shoulder level (Figure 1-10).

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Wristlets may be used instead of the chest or body harness, if the employer can prove that the wristlets are a safer and more effective choice. The other end of the retrieval line has to be attached to a mechanical device or fixed point outside the permit space, so rescue can take place when it is necessary. A mechanical device has to be used if the space is more than 5 feet deep, vertically.

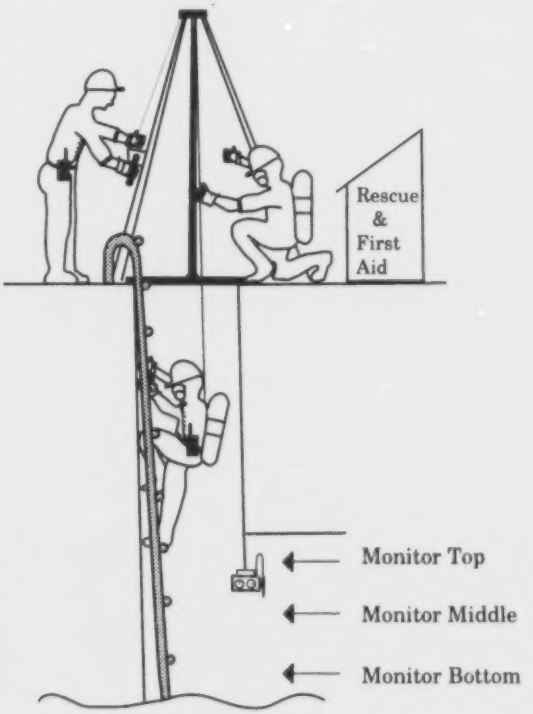

Figure 1-10
Retrieval System

A material safety data sheet (MSDS) or written information has to be made available to a medical facility treating an exposed entrant who has been injured. Medical personnel who have chemical information on the circumstances surrounding an injury will be able to treat you more affectively, so you can recover quicker.

BACK INJURY PREVENTION

The following information has been adapted from the Laborers' Health and Safety Fund of North America, "Back Injury Prevention Program." It contains important back injury information.

A Swedish study of construction apprentices found that their back problems rose from 18% to 40% by the end of their second year of work. In Canada, nearly 25% of the lost-time injuries in construction have originated from back injuries (Figure 1-11).

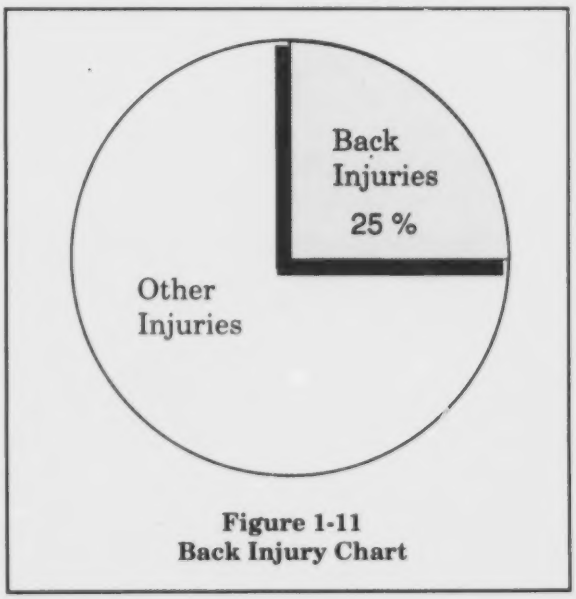

Figure 1-11
Back Injury Chart

Pain in the back and joints is a leading factor in forced retirement from the construction trades and for workers looking for less demanding occupations. These changes are often accompanied by a serious reduction in living standard.

Back injuries have cost workers and employers 93 million lost work days every year. You have a one-in-four chance of losing time on the job from a back injury. This means that 130,000 LIUNA members suffer back injuries each year. The price for each injury is about $9,000 in direct costs, not including lost wages, and added emotional stress. It is time to take action to prevent these back injuries from occurring at such an alarming rate.

This section will tell you how to keep your back healthy through exercise and stretching. It will give preventative tips, such as safe lifting techniques, so you can prevent back injuries. It will also give you information for managing your injured back.

Maintain a Healthy Back

General health involves good eating habits and regular exercise, such as walking, which keeps off excess weight. Good body posture will also help keep your back healthy. If you suffer from a back injury, it will probably happen sometime in your adult years. Most back injuries are accidents, but these injuries are not usually permanent. You will recover! If you are healthy, you will recover sooner than if you are unhealthy.

Stress can occur on the job or at home. Back injuries can increase the stress in your life. First, you need to deal with that stress by acknowledging it, then you can work on ways to decrease or eliminate that stress. If you are in good general health, back injuries can be a lot less stressful, because you know that you will recover from the injury sooner.

The exercise that you get on-the-job is probably different from the general exercise that you need to keep your back healthy. Exercise at the job site comes in short bursts. Sustained periods of exercise (at least 20 minutes) have to be devoted to a general exercise program to keep your back healthy. Walking is great exercise. Walking uses every muscle in your body, especially your heart. If you can take a twenty-minute walk three times a week, you will feel healthier. You may walk at work, but it is stop and go walking instead of constant walking.

Walking will keep excess weight off which will also help to keep your back healthy. A big stomach puts extra stress on your back. If you lose the weight, you will feel better and will be able to move and lift easier. Try strapping a 10 or 20 pound bag of potatoes to your stomach and see how much stress is placed on your back. That's what happens when you have excess weight in your stomach area.

Posture maintains a healthy back. Keep your shoulders straight and your back straight. Even if you are only a little stooped over, you will have an increased risk for sustaining back problems.

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Back Injury Management

Over eighty percent of back injuries get better in a short time period (from several days to a few weeks). Most back injuries do not involve the disc. A "ruptured" disc is an old, inaccurate term. Most injuries involve the many ligaments, joints, or muscles in the back. This means you should keep moving gently, within the limits of your back pain. You should gradually improve, feeling less discomfort and more movement as the days go on. If you don't improve, call your physician if you experience any of the following symptoms:

- Constant pain with no relief at all.
- Pain or numbness below the knees.
- Involuntary release of the bowel or bladder.
- Any change in your discomfort level.

Taking Care of Your Own Back

If your doctor says you can take aspirin or other mild medications to reduce the discomfort and possible inflammation, take them according to the physician's suggestions. There are other things you can do to reduce back pain. Within the first three days after the injury, put an ice compress on the area. After that you should be able to stand in the shower and let the warm water run down your back. When you are in bed, lie on your side with a pillow under your head and another pillow between your knees. Bring your knees towards your chest, so you can bend at the hips and knees. With the pillow between your knees, you should feel comfortable. Do not lie on your stomach. This position puts too much strain on the back. If you must lie on your back, place a pillow under your knees to take the pressure off the low back area.

As the discomfort decreases, try to move your legs and hips in bed. Slowly at first, then with slightly increased speed as you feel better. If the hurt area starts to feel worse, stop! When you feel the muscles and joints relax and loosen up in the discomfort area, you can start to get out of bed. To get out of bed, roll on your side so your face is at the edge of the bed. Bend your hips and let the bend in your knees reach outside the edge of the bed. Slowly lift your legs off the edge of the bed and use your arm to help push you into the sitting posture. Now stand up.

If you stand as straight as you can, try to arch the small of your back by looking at the ceiling. Walking will help your injury heal. Walk around the house using a straight posture. Try to walk a little farther each time. When you get tired, lie down on your side and put ice on your back. Do not sit in your easy chair. Sitting is bad for you in the very beginning of a back injury. Stand up when you want to eat. You may want to sit on the edge of a high stool at the kitchen counter top while resting your feet on the floor.

As you start to feel better, start walking longer distances. Continue to avoid sitting as much as possible. Lie on the sofa when watching television. If you must drive, use a lumbar support placed in the small of your back. A lumbar support is something that is round, made

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of soft but firm material, that is approximately five inches in diameter. A lumbar support helps you to keep the small of your back in the proper curved position. Use a bath towel tightly rolled up with some tape as a lumbar support substitute. When you sit in a car, place this roll in the small of your back.

When you go back to work, STOP, LOOK, and LISTEN before you lift anything. Remember to get help from a fellow worker when lifting large bulky items.

Preventing Back Injuries

Accidents can cause back injuries. To minimize the chances of accidental back injury, STOP, LOOK, and LISTEN!

STOP! Think about what you will be lifting. Is it heavy, light, bulky? Ask yourself, "What lifting techniques will I use?" The way you lift will determine if you are at risk for injuring your back. You need to lift with a straight back. Keep the curve in the small of your back straight as you lift. Use your leg muscles. Your leg muscles are a lot bigger and stronger than your back muscles; use them! Keep the load close to your body. The important thing is to STOP before you lift! Think about proper lifting techniques.

LOOK! Look around and ask yourself some important questions. "Am I on uneven ground or in a cramped spot? Am I able to get where I am going without tripping? Do I have to twist my body to lift?" Look for all these things, and plan your lift. A few seconds could save you a few weeks of back discomfort.

LISTEN! Listen to your body, to your co-workers, and listen to your brain about the proper lifting techniques. If you feel awkward when you are lifting, then do not make the lift! If you need help from a co-worker, get it! Help co-workers make awkward lifts. Remember the proper ways to lift. A few minutes in preparation saves a few days with back pain.

Spinal Column

The spinal column is made up of vertebrae (Figure 1-12). Like other parts of the skeleton, they provide support and form the structure where muscles are attached.

The spine also provides a bony protective cover for the spinal cord. This cord can be compared to a telephone cable carrying information inside hundreds of tiny wires. Each wire carries messages from the brain to certain parts of the body. Information about the condition of the body is brought back to the brain.

The spine is a unique part of the skeleton because it provides support and allows free movement of the upper body or trunk. Movement is made possible by spinal discs which are wafers of cartilage tying vertebra together. Each vertebra is linked by facet joints. The discs act as shock absorbers, cushioning loads and allowing movement.

Muscles

Movement of the human body is controlled by the tightening and releasing of the muscles. Ligaments support and strengthen the joints, preventing abnormal movement. Muscles are controlled by messages sent from the brain along the nervous system.

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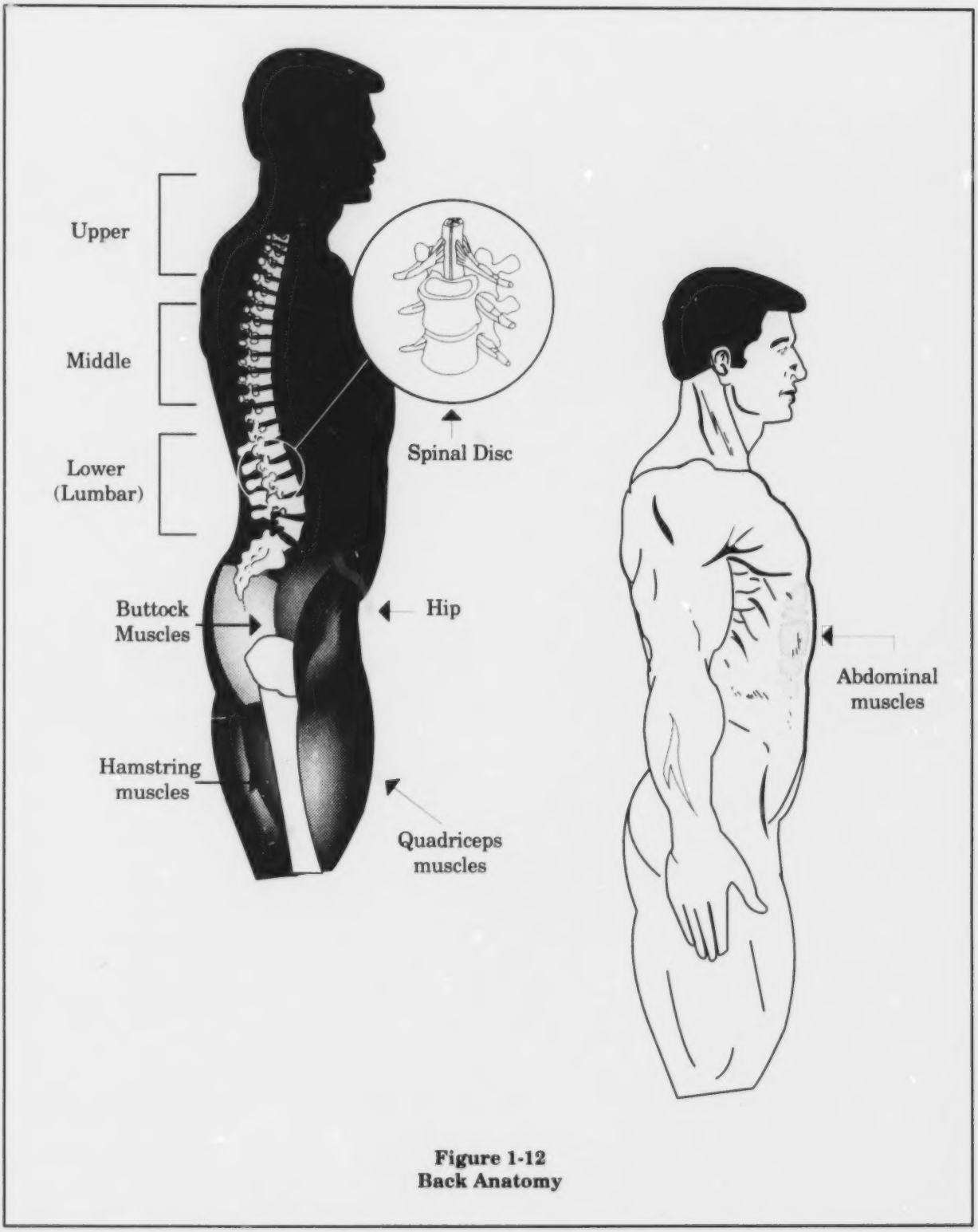

Figure 1-12
Back Anatomy

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The spine is the only bony support for the body between the rib cage and the hip bones. This allows movement in the lower back or lumbar section. Because of this lack of bone in the lower back, the body depends on an interwoven set of heavy muscles and flat sheets of strong ligaments across the abdomen and lower back. These muscles provide support to the back, so they need to be kept in good condition.

The most common site of injury is in the lower back just above the pelvis. Because the pelvis and sacrum are relatively rigid, this is the point on the spine which takes the most strain when we bend, twist, or lift.

Muscles can work either dynamically or statically. Dynamic work involves a muscle tightening and relaxing. Static work involves a muscle in constant contraction without joint movement. Static work over a period of time causes muscular pain due to a build-up of lactic acid. Relaxing the muscle will circulate oxygen-carrying blood through the tissues and restore them to normal. To relax these muscles, you will need to change your work technique to place less strain on the back. This will take practice.

Training for Strength and Fitness

Muscles must be kept in good condition. They must be strong, flexible, and have good endurance. This is important to prevent injuries.

You need to warm up your muscles before you work, just like an athlete warms their muscles before they compete. You should limber up before lifting. *Studies have shown that construction workers hurt their backs on the first heavy lift of the day.* A pre-work warm-up will help you prevent these injuries, especially in cold weather when muscles are less flexible. A regular exercise program will also prevent injuries (Figure 1-13a to 1-13k). A good exercise program should consist of four basic parts:

- Stretching
- Warm-up
- Strengthening
- Stretching

Since there are many muscles in the back, you need to strengthen and stretch the back on a regular basis. It is important to warm up the back before you attempt to make any lifts in order to prevent injury to the back. There are four pre-work warm-ups illustrated in this manual. They are:

- Jumping Jacks
- Walking in Place
- Back Stretch
- Standing Knee Bend

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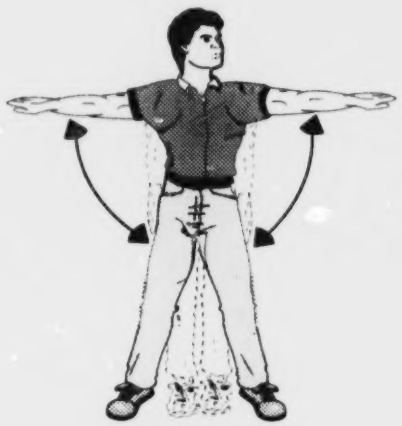

Figure 1-13a
Jumping Jacks

Jumping jacks are a classic warm-up exercise. Jump lightly in place, raise your arms while moving your legs apart.

Figure 1-13b
Walk in Place

Walk in place with an exaggerated arm swing.

Figure 1-13c
Back Stretch

Slowly bend backwards to a comfortable position while standing. Support your lower back with your hands.

Figure 1-13d
Standing Knee Bend

Raise your bent knee to a comfortable position towards your chest. Cup your hands under your bent knee for support.

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The following diagrams will help you increase the strength and flexibility in your back:

Figure 1-13e
Side Stretch

Stretch your arm over your head. Slowly bend to the opposite side. Alternate sides and repeat.

Figure 1-13f
Head Turn

Tuck in your chin. Turn your head slowly from side to side. Repeat.

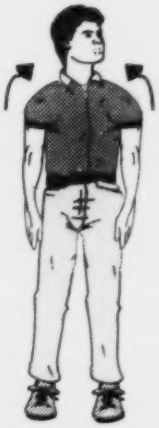

Figure 1-13g
Shoulder Shrug

Raise both shoulders as high as comfortable towards your chin. Alternate sides and repeat.

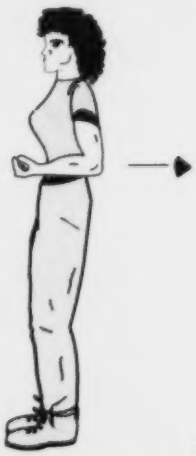

Figure 1-13h
Standing Elbow Press

Bring your elbows to chest height. Press them gently backwards to a comfortable stretch. Repeat.

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Figure 1-13i
Upper Back Stretch

Extend your arm over your head while laying down.

Figure 1-13j
Knee to Chest

Pull your bent knee towards your chest while laying on your back. Keep your lower back and your other leg pressed against the floor. Alternate sides and repeat.

Figure 1-13k
Elbow Press

Keep your head straight and lean on your forearms. Keep your hips and abdomen pressed against the floor.

There are times when you should consult your doctor immediately. Avoid exercise completely, when:

- You have pain in the leg below the knee.
- You have weakness, numbness, or pins and needles in foot or toes.
- You have back pain after a recent accident.
- You have bladder problems after recent back pain.
- You are not feeling well in conjunction with back pain.

Lifting Techniques on the Job

Have you ever watched experienced workers make a lift? Those workers will know how to lift correctly. They have learned the most efficient way to lift items over time. What has lifting experience taught them? Here is a summary of the techniques they do correctly (Figure 1-14a to 1-14h):

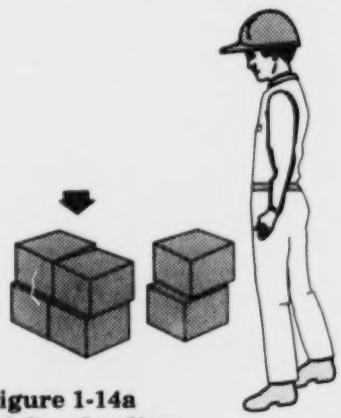

Figure 1-14a
Avoid Overloading

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- Pushes the load to find how much it weighs.
- Breaks larger loads into smaller ones.
- Keeps their back as straight as possible when lifting.

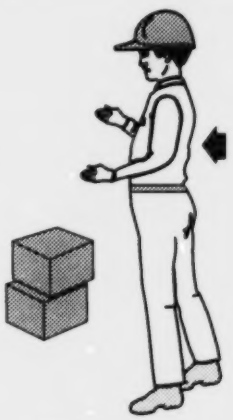

Figure 1-14b
Straighten Back

- Tightens stomach muscles.

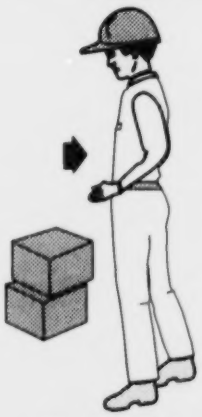

Figure 1-14c
Tighten Stomach Muscles

- Uses their stomach, buttocks, and leg muscles to lift and to set the load down.
- Bends at their hips.

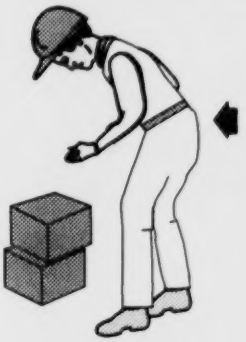

Figure 1-14d
Bend at the Hips

- Bendss their knees.

Figure 1-14e
Bend the Knees

- Grips with their hands, not their fingers. Wears tight-fitting gloves.
- Keeps the load as close as possible to their body. (It places less strain on the muscles, ligaments, and joints, when the load is closer to the body.)

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Figure 1-14f
Position the Load

- Lifts with their leg muscles because they are stronger than the back muscles.

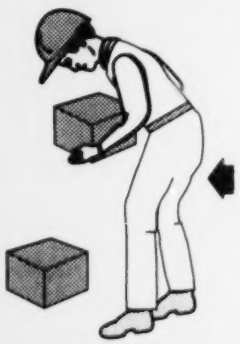

Figure 1-14g
Lift with the Legs

- Makes sure the load is balanced.
- Never twists their back when they lift. They move the legs instead of twisting or turning.

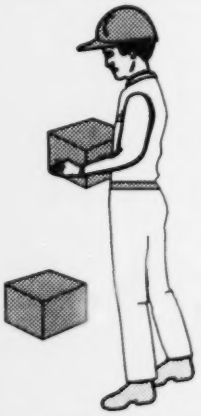

Figure 1-14h
Avoid Twisting

- Makes sure they can see where they are going.

Other lifting techniques experienced workers may use:

- Lift at waist level when possible.
- Never lift or carry over the head.
- Keep pathways clear.
- Find a better way.
- Get lifting help.
- Push, don't pull.
- Solve heavy load lifts and repetitive lifts.
- Use mechanical help.

Shoveling

There are many times when you are laying pipe where you will need to shovel material. Never twist your body when you shovel! Practice the following techniques to prevent back injuries on the job (Figures 1-15a to 1-15b):

- Keep your feet wide apart.

Figure 1-15a
Position Feet

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- Keep your front foot close to the shovel.
- Put your weight on the front foot.

Figure 1-15b
Shift Weight

- Shift your weight to the rear foot.
- Keep the load close to your body.

Figure 1-15c
Load Close to Body

- Turn your feet in the direction of the throw.

Figure 1-15d
Turn your Feet

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SECTION I ASSIGNMENT SHEETS

Place the proper letter beside the correct definition.

a. Sloping

b. Wales

c. Sheeting

d. Benching

e. Trench

f. Competent Person

g. Slope Ratio

h. Uprights

i. Excavation

j. Cross Braces

_____ means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

_____ means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

_____ means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

_____ means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

_____ means a horizontal to vertical relationship with the horizontal expressed first, and the vertical always expressed as one.

_____ means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation to prevent cave-ins.

_____ means a narrow excavation (in relation to its length) made below the surface of the ground.

_____ mean the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not touch each other.

_____ means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

_____ mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, with the ends bearing against either uprights or wales.

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Match the following sloping requirements with the soil types:

Sloping Requirements:	Soil Types:
a. Vertical	_____ An excavation in gravel material with an unconfined compressive strength of 0.5 tsf or less.
b. 1 1/2:1	_____ An excavation 10 feet deep in cohesive soil with an unconfined compressive strength of 1.5 tsf (for only 12 hours).
c. 3/4:1	_____ An excavation in cohesive, fissured soil with an unconfined compressive strength of 1.5 tsf.
d. 1/2:1	_____ An excavation in cohesive soil with an unconfined compressive strength of 1.5, but was previously excavated.
e. 1:1	_____ An excavation in stable rock.

Answer the following questions:

1. What are three types of cave-in protection systems?_____

_____

2. Who is required to inspect an excavation?_____

_____

3. When are these inspections required?_____

_____

4. Describe three warning signs of a pre-existing excavation or a buried utility.

_____

5. Describe three types of hazardous atmospheres and physical characteristics for each.

_____

_____

_____

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Answer the following permit required space questions:

6. Name three permit system requirements.

7. What is the definition of a confined space?

8. When is a permit needed inside confined space?

9. When should you exit a permit space as quickly as possible?

10. List the duties of a permit space attendant.

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11. List four situations when an attendant must evacuate a confined space.

Answer the following back injury questions:

12. What is one exercise that can help keep your back healthy? How often and for how long should you perform this exercise?

13. What is the most comfortable resting position when you have a back injury?

14. What are four symptoms of back pain that will help you decide to visit a doctor?

15. When do construction workers usually hurt their backs and how can this injury be avoided?

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SECTION II: PRESSURE PIPE LAYING TECHNIQUES

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Trainee Objectives

Describe the responsibilities of the lead pipelayer, tail pipelayer, and the top man on a pipe crew.

Identify the following tools and pipe appurtenances:

Corporation Stop	Tee Bolt
Curb Stop	Flaring Tool
Tapping Saddle	Tapping Machine
All-thread	Dresser Coupling
Eye Bolt	Wrap-around Repair Clamp

Become competent in joining pipe sections using Mechanical and Push-on Joint connections.

Become familiar with common water pipe installations and assembly techniques.

Become competent with common hydrostatic testing procedures and test pump set-up and operation.

Become competent in tapping and assembling a water service connection.

Become competent at operating a portable all-purpose saw.

Become competent at fusing polyethylene pipe.

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TERMS AND DEFINITIONS

All Thread: A long threaded rod that can be cut into custom-sized pieces so that nuts can be attached to the rod. Used in many different applications when no manufactured bolt exists.

Appurtenance: Accessories that are added or joined to something else.

Beveled: To fix or cut the edge of a pipe at an angle.

Bleed Valve: Installed at high points in the pipe to bleed the air inside the pipe. Usually consists of a corporation stop and curb stop connected by 3/4" TYPE K copper tubing.

Corporation Stop: Used to move water from the main water line along a service water line to a building, usually a house or business. It is a valve tapped into the main line or threaded into a service saddle. It is kept in the "on" position after the service water line is completed.

Curb Stop: This is a valve located close to the property line of a home or business that can be turned on or off by the utility company or the owner.

Double Edge Facer: A cutting attachment found on a pipe fusion machine. It is a plate with cutting blades that rotate to cut the ends of the pipe to allow for a smooth fit of the pipe ends.

Dresser Coupling: A coupling used to join a section of broken pipe or connect different types and diameters of pipe together.

Excavator: Any machine or power shovel that removes the earth to form an excavation.

Flaring Tool: A tool that is placed into copper tubing after the flaring nut. It is then struck with a hammer to form a flared end. The flared end creates a water tight seal after the flaring nut is tightened.

Hydrostatic Pressure Test: The process of removing the remaining air from the pipe line and applying the required test pressure according to specifications.

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Open Bore Flushing:	A method used to flush dirt and debris from a pipe. The water rushes from the start of the line through the full opening at the end of the line. The water is usually pointed away from the excavation to prevent flooding.
Plumb:	To place straight up and down at true vertical alignment.
Pup:	A short piece of pipe used to join pipe or pipe parts.
Spigot:	The straight end or male end of a pipe.
Stop and Waste Valve:	Used in colder climates. Allows water to drain back from the serviced building to the main line to prevent freezing. Always marked with an arrow to show the proper direction of flow.
Tapping Machine:	Capable of drilling a hole and cutting threads in the pressurized main line so the corporation stop can be installed.
Tapping Saddle:	Used to install a corporation valve in main lines, especially those made of plastic or PVC.
Teflon Tape:	A stretchy trademark tape that is waxy and white. It is stretched around threads to help prevent leaks.
Three-Part Union:	A pipe part used to connect two sections of flared TYPE K copper pipe.
Thrust Blocking:	Concrete (either poured in place or pre-poured) that is placed against an excavation wall and around a bend or tee, to prevent mechanical joints from separating during pressure surges. Also called "being kicked."
Torque:	A turning or twisting force placed on pipe nuts.
Wrap-Around Clamp:	A repair clamp used to patch small holes or cracks in pipe.

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CREW RESPONSIBILITIES

Pipe laying crews usually consist of six workers, each with specific tasks to perform. These workers must work together as a unit to ensure that safety is maintained during pipe laying operations.

The foreman is responsible for the performance of the crew and the efficient completion of the project. He must plan for safety, such as shoring or sloping of excavation walls, the right equipment needed for the project, and he must arrange to have the right parts and number of parts or materials to complete the project.

The top man has numerous tasks to perform. He works with the foreman in laying out pipe lengths and parts. He assembles valves and other parts to be lowered into the excavation. The top man assists the pipelayer by handing down tools needed for pipe installation and rigging of pipe sections to be lowered into the trench by the backhoe. Other duties include maintaining the operation of water pumps and observing the excavation walls for warning signs of cave-ins and locations of existing structures.

The lead pipelayer is generally the most experienced member of the pipe crew and works closely with the excavator operator. Using hand signals and head nods, the pipelayer guides the operator around existing utilities. Lead pipelayers set the depth of excavation for pipe grade and lowering of pipe sections into the trench for installation. The lead pipelayer must be familiar with the type of installation being used and all the recommended installation procedures. He is also responsible for the correct grade and alignment of the pipe.

The tail pipelayer is the lead pipelayer's assistant. He cleans and lubricates the pipe ends and helps guide the pipe sections together. The tail pipelayer keeps ladders close by, and makes sure all hand and power tools used are in good working condition. Tail pipelayers backfill and compact along the sides of the pipe.

The excavator operator is responsible for digging a safe trench and placing excavated material or "spoil" far enough from the excavation opening to meet regulations on overloading of the trench walls and hazards to the workers in the trench. He works closely with the lead pipelayer setting final grade, lowering pipe sections, and carefully placing backfill on the newly laid pipe. The excavator operator also keeps a close eye on the walls of the trench for cave-ins.

The backfill operator must always be alert for workers in the trench and for signs of cave-ins. He must carefully backfill around the pipe and place backfill material in lifts for proper compaction. The backfill operator is responsible for cleaning up the site behind the pipe laying operation and preparing the site for further development.

PIPE PARTS AND APPURTENANCES

The following illustrations describe some of the common tools and pipe parts for

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main line water distribution systems. Area practices and piping systems vary greatly from area to area, so become familiar with your project's plumbing code and specifications.

A flaring tool is used to flare the end of "Type K" copper piping. The small diameter end of the tool is inserted into the piping (after the flare nut) and the larger end is struck with a hammer until the copper pipe is stretched into the shape of the notch, (shown in the cut-away section on top of Figure 2-1). When tightened, the flare nut will seat the copper flare to make a water tight connection.

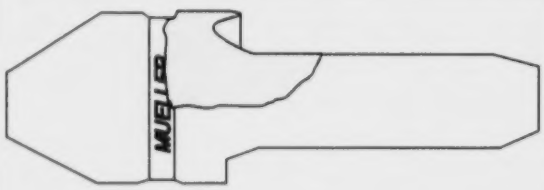

Figure 2-1
Flaring Tool

A 3-part union (Figure 2-2) is used to connect two sections of "Type K" copper piping together. The copper piping must be correctly flared to match the shape of the seats and care must be taken to ensure that the fittings have no dirt,

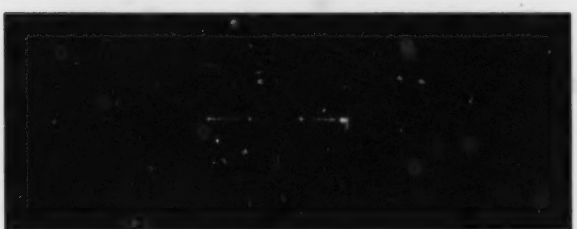

Figure 2-2
3-Part Union

Figure 2-3
Corporation Valve

debris, or cutting burrs on the areas where the copper will seat.

A corporation valve (Figure 2-3) is used to distribute water from a main to a house or business. The valve is drilled and threaded into the main distribution line or into what is called a tapping saddle mounted on the main line (Figure 2-4).

Figure 2-4
Tapping Saddle

This valve will be left in the "on" position after the service water line is completed and the Curb Valve is turned "off."

A tapping saddle will be used whenever it is not possible to tap the corporation valve directly into the main line.

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Main lines constructed of plastic pipe, such as PVC are a good example. The manufacturers will not guarantee the corporation valve will remain threaded directly into the main after full operating or testing pressures have been applied to the line. A tapping saddle is recommended for use on all service installations in plastic pipe.

A curb valve (Figure 2-5) is used at or close to the property line of the residence or business. The valve will be turned on or off by the utility or property owner as needed. In areas with severe freezing weather, a modification of this valve called a "stop and waste" will often be used. The stop and waste valve will allow water to drain back from the serviced building to prevent freezing of the service line. Stop and waste valves are always marked with an arrow indicating the correct direction of flow. During installation, make sure the arrow is pointed towards the building to be serviced.

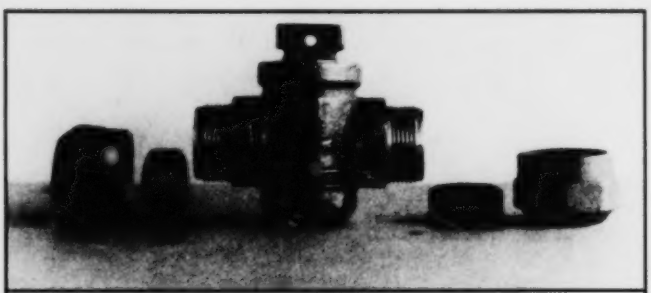

Figure 2-5
Curb Valve

Figure 2-6 shows a standard installation of a mechanical joint and "all-thread." Most plumbing codes require fire hydrants, valves, and building fire line installations be all-threaded. This procedure is commonly called "tie back" or "rodding." The purpose is to prevent the mechanical joints from separating during the severe water pressure surges that can be expected during fire fighting operations. Note the use and locations of the tee bolts connecting the mechanical joint, and the use and location of the eye bolt mounting the all-thread.

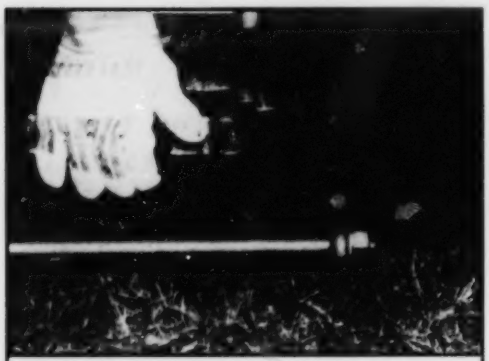

Figure 2-6
Tee bolts, eye bolt, and all-thread

A wrap-around repair clamp (Figure 2-7) can be used to patch holes or small cracks in the pipe. When the tightening nuts are removed, the clamp can be spread out into a sheet that can be placed under and around the pipe then tightened. As with all pipe part installations, make sure the

Figure 2-7
Wrap-Around Repair Clamp

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area to be repaired is clean and free of debris before installing the repair clamp.

Dresser couplings can be used to replace a section of broken pipe. They can also be used to connect different types and diameters together. Figure 2-8 depicts a section of PVC being replaced with a section of ductile iron and connected with dresser couplings at each end.

Figure 2-8
Dresser Coupling

MECHANICAL JOINT ASSEMBLY

As shown in Figure 2-9, a typical mechanical joint for ductile iron pipe consists of a gland (flange), a rubber gasket, and tee bolts.

The cast iron gland is slipped on the spigot end with the lip extension toward the joint. Next, the rubber gasket is placed on the spigot end with the thick edge toward the gland. The entire section of pipe is pushed forward to seat the spigot into the bell. Using the gland or a hammer to slide the gasket, carefully seat the gasket evenly around the entire joint. Insert the tee bolts in the bell end of the pipe and through the gland. Nuts must be tightened alternately in order to

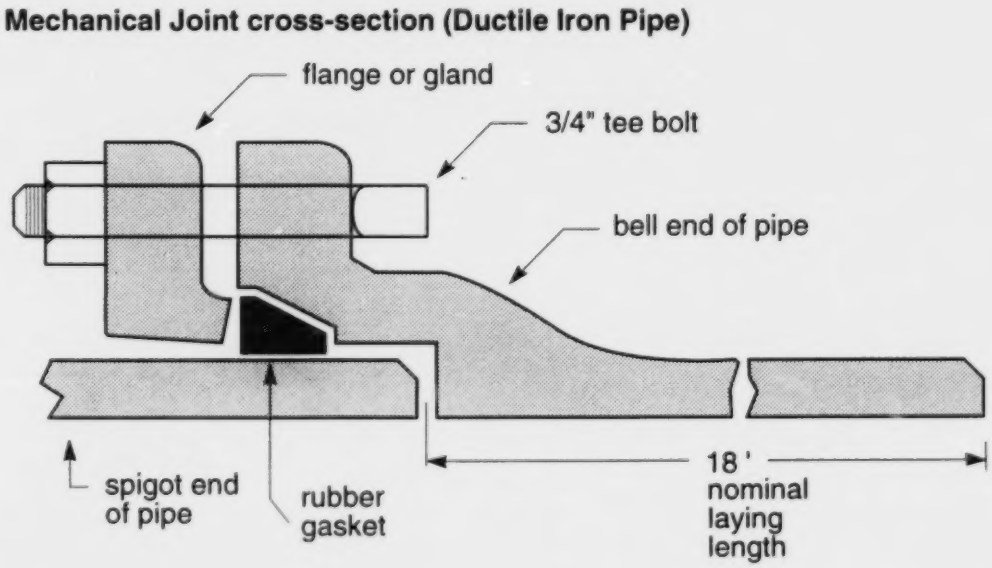

Figure 2-9
Mechanical Joint

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Torquing Bolts on Mechanical Joints

TIGHTENING ORDER
1-2, 3-4, 5-6, 7-8

ROTATIONAL ORDER
1,5,3,7,2,6,4,8

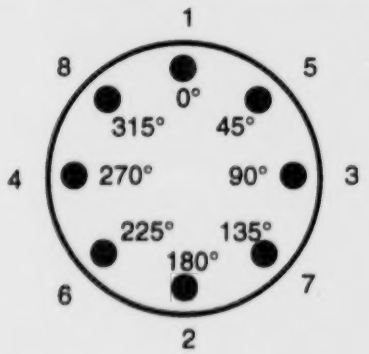
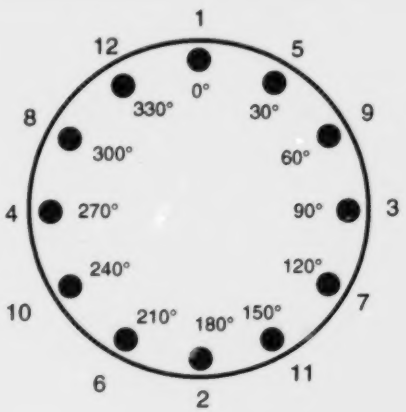


Figure 2-10: 8 Bolt Torque Sequence



TIGHTENING ORDER
1-2, 3-4, 5-6, 7-8, 9-10, 11-12

ROTATIONAL ORDER
1,5,9,3,7,11,2,6,10,4,8,12

Figure 2-11: 12 Bolt Torque Sequence

TIGHTENING ORDER
1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16

ROTATIONAL ORDER
1,9,5,13,3,11,7,15,2,10,6,14,4,12,8,16

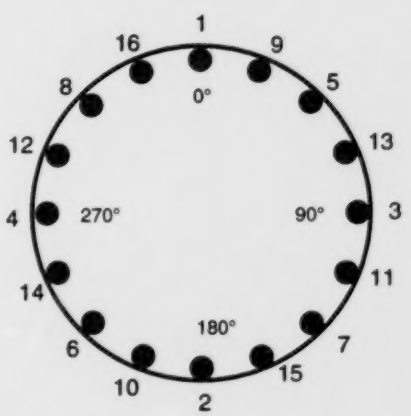


Figure 2-12: 16 Bolt Torque Sequence

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produce an equal pressure on all parts of the gland as shown in Figures 2-10 to 2-12. The following procedure should be used for application of bolt torque.

Certain steps must be followed when torquing bolts on mechanical joints:

Step 1. Install all nuts and bolts finger tight.

Step 2. Apply torque in 20% steps of required final torque.

Step 3. Tighten bolts in sequential order 0°-180°, 90°-270°, etc., at each step until final torque is reached.

Step 4. Use rotational order until all bolts are stable at final torque level.

TYTON OR PUSH-ON JOINT ASSEMBLY

The Tyton Joint (Figure 2-13) can also be called "push-on" or "slip-on" joint. Unlike a mechanical joint, it requires no bolts or tightening system. This joint relies on pressure exerted from the gasket to produce a water tight seal. During installation of this joint, the pipelayer must watch the insertion closely noting any signs of an improper insertion. The spigot end of Tyton joint pipe is marked with several white bands that indicate the proper depth of insertion. If more than one of these white bands are visible after insertion, the joint has not been inserted fully. Another sign of an improper insertion is a spring back of the joint after the insertion pressure has been relieved. The spring back may indicate that the pipe did not slide on the gasket, instead the gasket may have

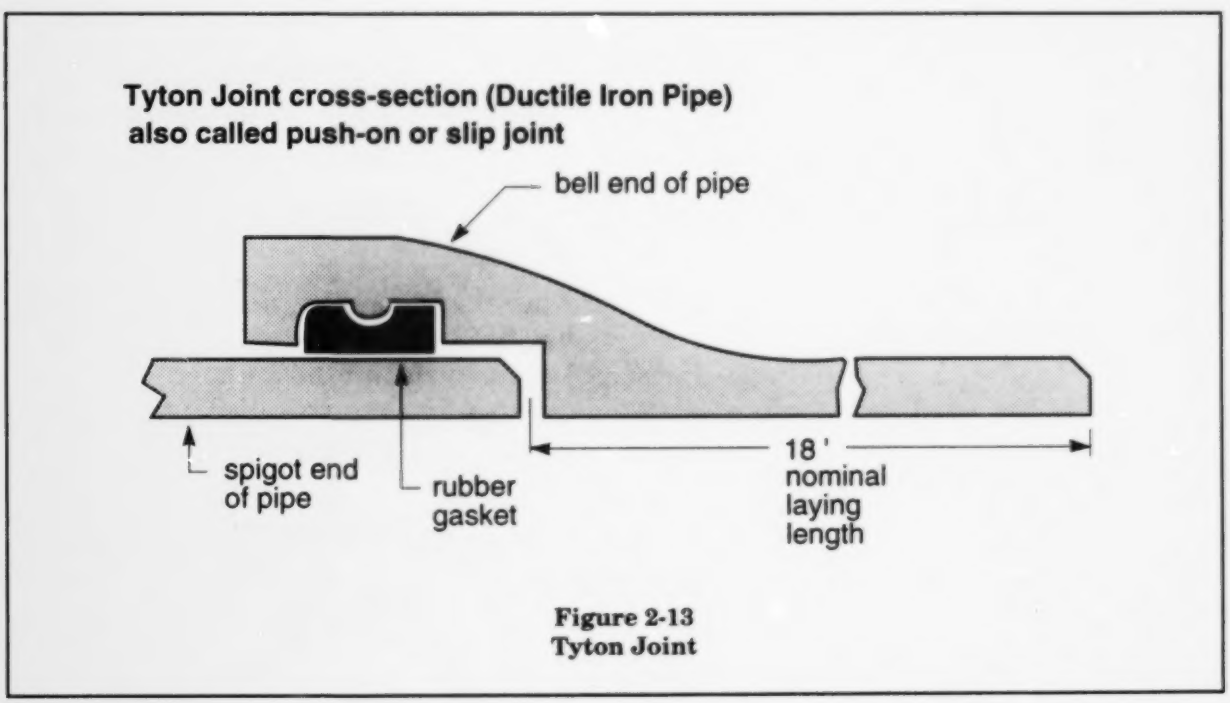

Figure 2-13
Tyton Joint

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rolled in with the joint. If you are not absolutely sure that a complete insertion has occurred, remove the pipe, inspect the gasket, and re-insert with a new gasket if needed.

TYTON JOINT ASSEMBLY PROCEDURE

Step 1. The outside of the spigot and the inside of the bell must be thoroughly cleaned of all foreign matter.

Step 2. Water soluble, non-toxic lubricant, must be used on the spigot and the bell to help seat the rubber gasket. The lubricating material is usually supplied with the pipe and will allow the pipe to slide in on the gasket and prevent the gasket from rolling or moving out of position.

Step 3. The tail pipelayer should have the bell of the previous joint lubricated and ready to receive the spigot of the next section. As the pipe is lowered into the excavation, the lead pipelayer will guide the bell while the tail pipelayer guides the spigot of the pipe into the bell of the previous joint. Insertion pressure can be applied by the lead pipelayer using a bar, or on larger pipe the excavator will apply pressure to insert the joint.

COMMON WATER PIPE INSTALLATION AND ASSEMBLY TECHNIQUES

Figure 2-14 shows a plan view of a main line water installation into a cul-de-sac. This plan view drawing is only an example. Symbols and piping techniques will vary in your area.

The plan shows that we tie into an existing 8 x 8 tee: the 8 x 8 indicates the mainline bore of the tee is 8" in diameter and the side bore is also 8" in diameter.

Our first step is to get the existing tee and any other utilities in the project area located. After the existing tee is located, our crew can begin excavating to expose the tee and connect to it.

The main line attached to the tee should be turned off, but as a pipelayer, you should never take things like that for granted. Even if the line is turned off, there still may be residual pressure in the line, enough pressure to blow a loosened cap or plug into your leg and cause serious injury. Always stand to the side of a cap or plug when loosening it, just in case.

After the cap or plug on the existing line has been removed, we can proceed with the installation of a short section of spigot to spigot pipe, called a "pup." This short piece of pipe will allow us to join the mechanical joint on the existing tee to a mechanical joint on the first proposed valve. The topman will have the pup and valve already bolted together on top of the excavation and waiting for the excavator to swing them down to the pipelayers.

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When the pipelayers have control of the pup and valve, they will guide the excavator and lower the section into place. The lead pipelayer will steady the end closest to the excavator and signal the excavator operator. The tail pipelayer will guide the spigot end into the existing tee. The topman should already have placed the gland and gasket needed to bolt into the existing tee onto the spigot end of the pup.

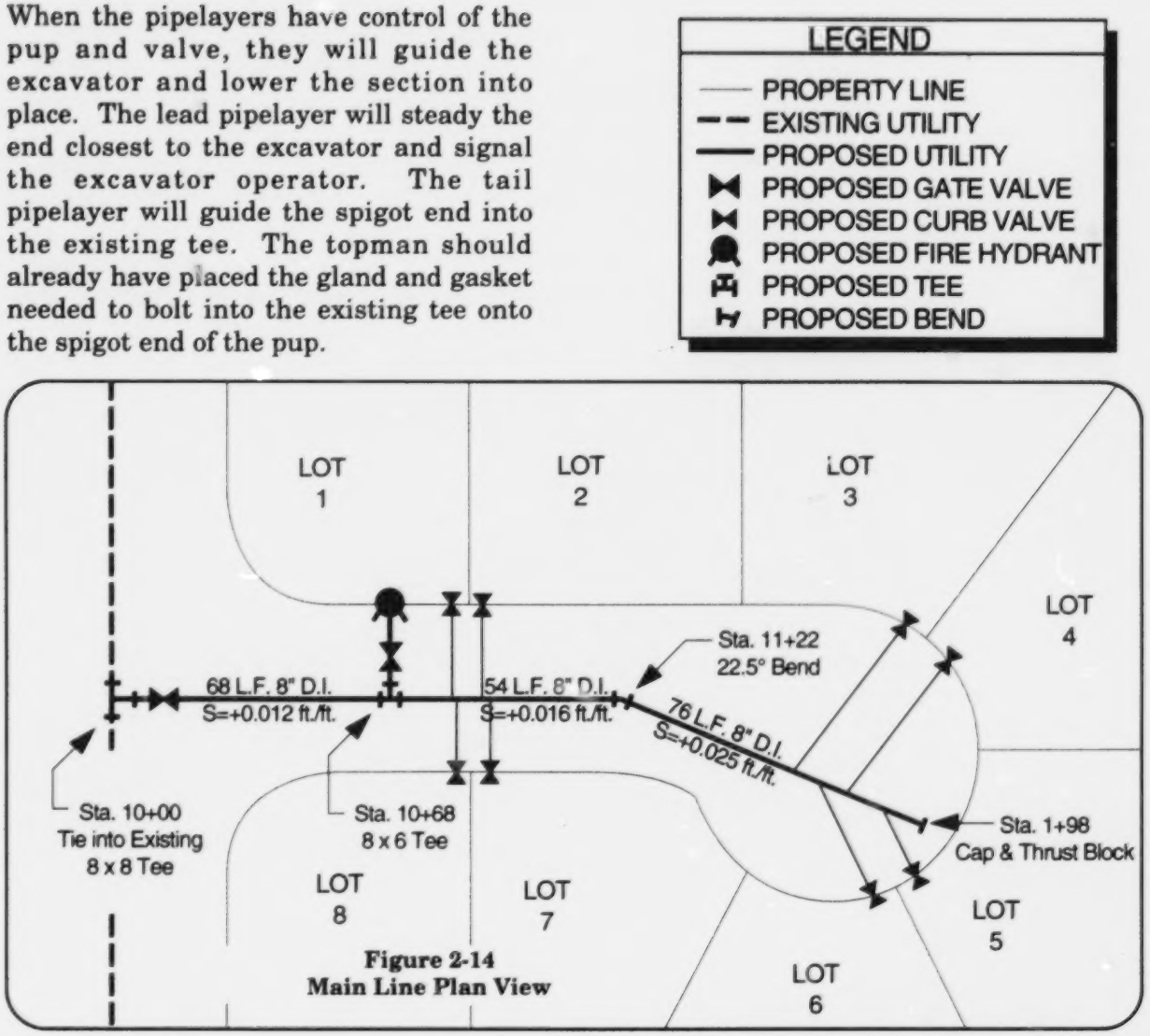

Figure 2-14
Main Line Plan View

Once the spigot is inserted into the existing tee, the tail pipelayer will begin bolting the mechanical joints together. It is <u>extremely important</u> for the pipelayers to double check the bolt torque on any joints that were assembled on top of the ditch. The processes of lowering pipe parts that are bolted together can loosen them, and it provides a second check of all mechanical joints.

As the bolting continues, the excavator will begin excavating for the next joint. With only one more mechanical joint for a straight section of around 60+ feet, it would be wise for our crew to begin using full joints of Tyton joint pipe. The Tyton joints do not need bolting and install very quickly.

The topman has coordinated with the foreman or engineer on the joint layout to make sure that he or she has enough

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joints laid out to stay ahead of the excavation. During the excavation process, the topman will continue to lay out and assemble as many mechanical joints on top of the ditch as possible. For example, in our plan drawing we see that the first section of pipe from the first proposed valve to the proposed 8 x 6 tee is ±60 feet.

This 60 feet can be divided by 18' (standard joint length of Ductile Iron Pipe) to determine how many full joints will be needed to reach the Fire Hydrant tee. Three joints of 18' each will result in 54' laying length. The balance of 6' will be made up using a pup. In this case, the pup should have two spigot ends to join a Tyton joint to the mechanical joint on the tee.

The topman will have to cut the 6' pup with an all-purpose saw. The type of cut made depends on the type of joint the pup will join. For example, the spigot end of the pup that will be joined to the Tyton joint should be cut straight and then beveled to allow for easy insertion. The end of the pup that will be joined to the mechanical joint can be left with a straight cut.

Once cut and bolted to the tee, the topman can cut a second pup with straight cuts on each end to join the tee with the hydrant valve.

Most plumbing specifications will require a fire line installation to be all-threaded. This tie back procedure is usually required on all piping from the main to the hydrant, but specifications will vary.

During the joining of the tee to the hydrant valve, the topman should install the all-thread tying the tee to the hydrant valve.

The whole assembly can then be swung into position and stabbed into the previous Tyton joint.

With the tee and hydrant valve installed, the next step is to install the hydrant itself.

Similar to the connection made from the tee to the hydrant valve, the connection from the hydrant valve to the hydrant must be rodded and connected with a pup. Also similar to the previous connection, neither of the ends of the cut will need beveling since we are connecting mechanical joints on each end.

The topman will have the hydrant and the pup bolted together by the time the excavator is finished excavating out to the design location. The whole assembly of hydrant and pup will then be lifted into place and secured. The excavator can remain hooked to the hydrant to steady it if needed.

On any valve or hydrant installation, make sure that the assembly is secured and backfilled plumb. The illustration in Figure 2-15 will show why.

The purpose of a valve riser is to allow the passage of a valve key that is shaped to fit over the operating nut. The collar, riser pipe, and top casting must be set and backfilled plumb. If these pieces are set too far out of line, or out of plumb, the key will not be able to fit over the operating nut on the valve.

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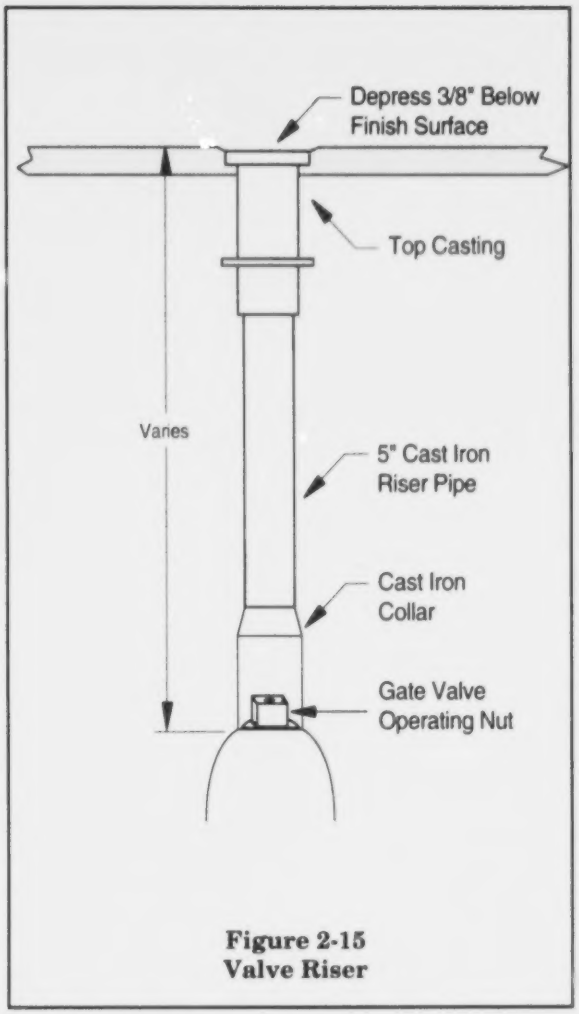

Figure 2-15
Valve Riser

One method that has been employed to keep the various valve riser pieces in a straight line and easy to plumb is to insert a 4 x 4 through all of the pieces and leave it in throughout the back-fill process.

Once the hydrant has been set and backfilled, the crew can continue on the mainline installation. Using full Tyton joints out of the hydrant tee, the tail pipelayer will bolt the mechanical joints together as the lead pipelayer works with the excavator to establish grade for the next joint of pipe.

The plan indicates a straight run of approximately 54 lineal feet to the next piping feature which is the 22.5° bend.

Once again, the topman will have the proper number of full joints and be performing whatever cuts that will be needed to complete this section of the utility.

When the excavation approaches the bend, the topman will begin any bolting needed to connect the bend and a pup together.

Standard specifications will generally require a feature, such as a bend or a tee (if not rodded) to be secured from pressure surges with what is called "thrust blocking." Thrust blocking consists of the placement of concrete around the feature and against an undisturbed excavation wall. Usually referred to as "being kicked," thrust blocking will prevent the mechanical joint from separating during pressure surges.

If the specifications require poured-in-place concrete, the piping feature will often have to be protected from the caustic effects of the concrete. This protection is often one or two layers of polyethylene plastic, wrapped around the fitting. Be sure to review the local plumbing code and project documents for clarification of this requirement.

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With the bend in place and "kicked," the last straight run of pipe is installed. Before the cap and thrust block is installed, the section of line should be flushed.

Commonly called "open bore flushing," the purpose is to remove dirt and debris that may have accumulated inside the pipe during the installation.

A method often used for open bore flushing is to install a 45° bend at the end of the line and run one joint of pipe up to the surface. When the water is turned on, the water will be pointed away from the excavation and will not be a problem during the removal of the 45° bend and extra joint of pipe.

Whenever a valve is turned on to allow water into a new section of line, it should NEVER be opened quickly. The resulting pressure surge from a quickly opened valve could blow your mechanical joints apart. Open the valve slowly and allow the normal operating pressure of the line to build up gradually over 3-5 minutes.

Once the flush has been conducted according to the project specifications, the next test in certifying the newly laid section is the pressure test.

Commonly called a "Hydrostatic Pressure Test," it is simply the process of bleeding as much remaining air from the line as possible and applying pressure up to the required test pressure in the project specifications.

In order to pass a pressure test, a large amount of air space cannot remain in the section. Air can be condensed and absorbed into the water or bled out through the joints. To adequately prepare for this air removal, the pipe crew must think ahead while still in the installation process.

Air will rise to the high points in the installation. In order to bleed the air from the high points, the pipelayer can place a bleed valve at those locations during the installation. The bleed valve will usually consist of a corporation stop and curb stop connected by 3/4" TYPE K copper.

Prior to the filling of the line with water, the corporation valve should be left in the open position, and the curb valve will be placed in the open position. As the filling is conducted, the curb valve will be closed only after all the air is removed and a steady stream of only water leaving the valve is noted.

Hydrants can be used as bleed valves as well and should be opened until a steady stream of water is noted.

While the air is being removed, the test pump can be attached to a bleed or fill valve located on the line. Figure 2-16 shows a hydrostatic test pump and gauge.

The test pump can be set up to draw from a bucket or drum, to allow for the calculation of the amount of water used to maintain the line at the test pressure, called "allowable leakage." An example formula is described later in this chapter.

A common testing criteria will be 150 psi maintained for 30 minutes. But the project specifications must be checked for differing criteria. For example, if the

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installation is to be used as a fire line or other specialized use, the specifications may require as high as 200 psi for as long as 24 hours.

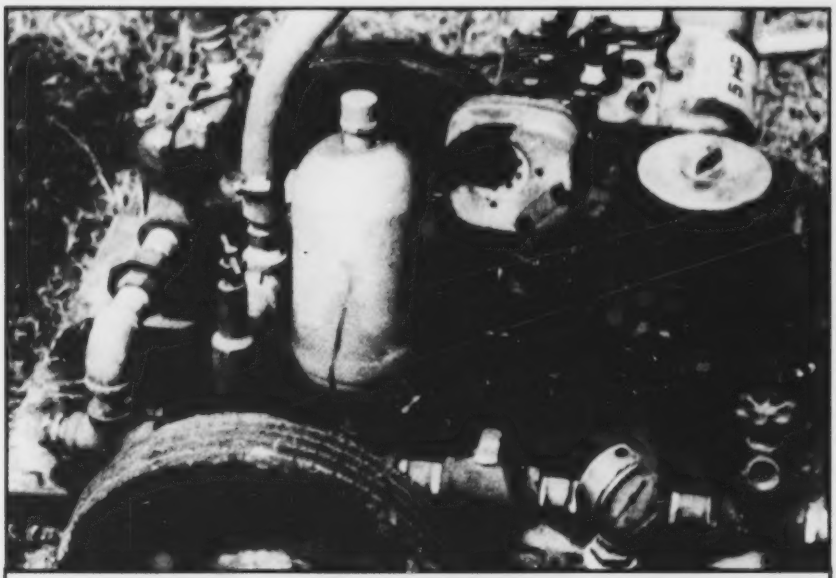

Figure 2-16
Hydrostatic Test Pump and Gauge

Once the pipe has been filled and tested, the next step will be to install the services. This is not usually done prior to the pressure test, so that the full test pressure is not exerted against all of the corporation valves. But once again, each project is unique and the project specifications and the local plumbing code must be consulted for differences.

HYDROSTATIC TESTING PROCEDURES

The purpose of a leakage and pressure test on water mains is to determine that the joints, fittings, and other appurtenances are secure and will not allow leakage beyond acceptance limits. The pressure test usually takes from 1 to 2 hours, and the pressures may vary from 1 1/2 times the static pressure, (that is, 1 1/2 times the normal operating pressure of the system), up to 200 psi.

The average pressure test will be at 150 psi. With proper installation and thrust blocking, the main will usually pass the test. There are many things that can cause a drastic drop in test pressure. Rolled gaskets, moved or loose fittings, and broken mains, all cause pressure problems.

A slow pressure drop may indicate an improperly cleaned joint, a poorly tightened mechanical joint, a scraped pipe or rubber gasket, or valves and hydrants are not completely closed. The most common problem is that all the air is not removed from the high points in the main line.

Testing Procedure:

1. Completely fill main with water, making sure all air is removed by opening hydrants or air release valves until water reaches these points, then close tightly.

2. Using a test pump, pressurize the main to the specified test pressure. This test pressure must be maintained for the full duration as specified by contract documents.

3. A sample allowable leakage formula is shown below, but your project may have different specifications.

GPH= (NxD) √P divided by 7,400

GPH= gallons per hour
N = number of joints under test
D = nominal diameter of main in inches
P = average test pressure in pounds per square inch

Find the number of gallons per hour (GPH) that is allowed to leak through 2,100 feet of 12" main, at a 150 psi test pressure. The pipe is installed in 20' sections.

N = 105 joints (2,100' of main divided by 20' lengths)
D = 12
P = 150

GPH= (NxD) √P divided by 7,400

= (105x12) √150 divided by 7,400
= 105x12x12.25 divided by 7,400
= 15,435 divided by 7,400
= 2.09 GPH

When different sizes of pipe are being tested during the same test, each size will have to be computed separately and the gallons per hour totalled.

TAPPING AND ASSEMBLING A WATER SERVICE CONNECTION

A valve called a corporation stop valve is drilled and tapped directly into the main line (Figure 2-17).

Figure 2-17
Corporation Stop Valve and Tapping Saddle

Direct tapping for a water service is accomplished using a tapping machine (most commonly a Mueller® B-100 series) which bores a hole and cuts threads into the main pipe. The machine is also used to install the corporation stop. Tapping may be accomplished while the main is under pressure.

Tapping Machine Maintenance

Before using the tapping machine (Figure 2-18), clean and lubricate all wearing and bearing surfaces and threads. *Do not lubricate the boring bar thrust collar.* Lubrication will shorten its service life.

The boring bar itself is lubricated between the upper and lower "O" ring seal by a reservoir containing a light machine oil. This reservoir must be filled occasionally.

Inspect and clean all tools and machine parts. Check the shank end of the combined drill and tap bit and the screw plug that mounts it for any burrs that may prevent proper alignment with the boring bar.

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MUELLER® B-100 and B-101 DRILLING AND TAPPING MACHINES

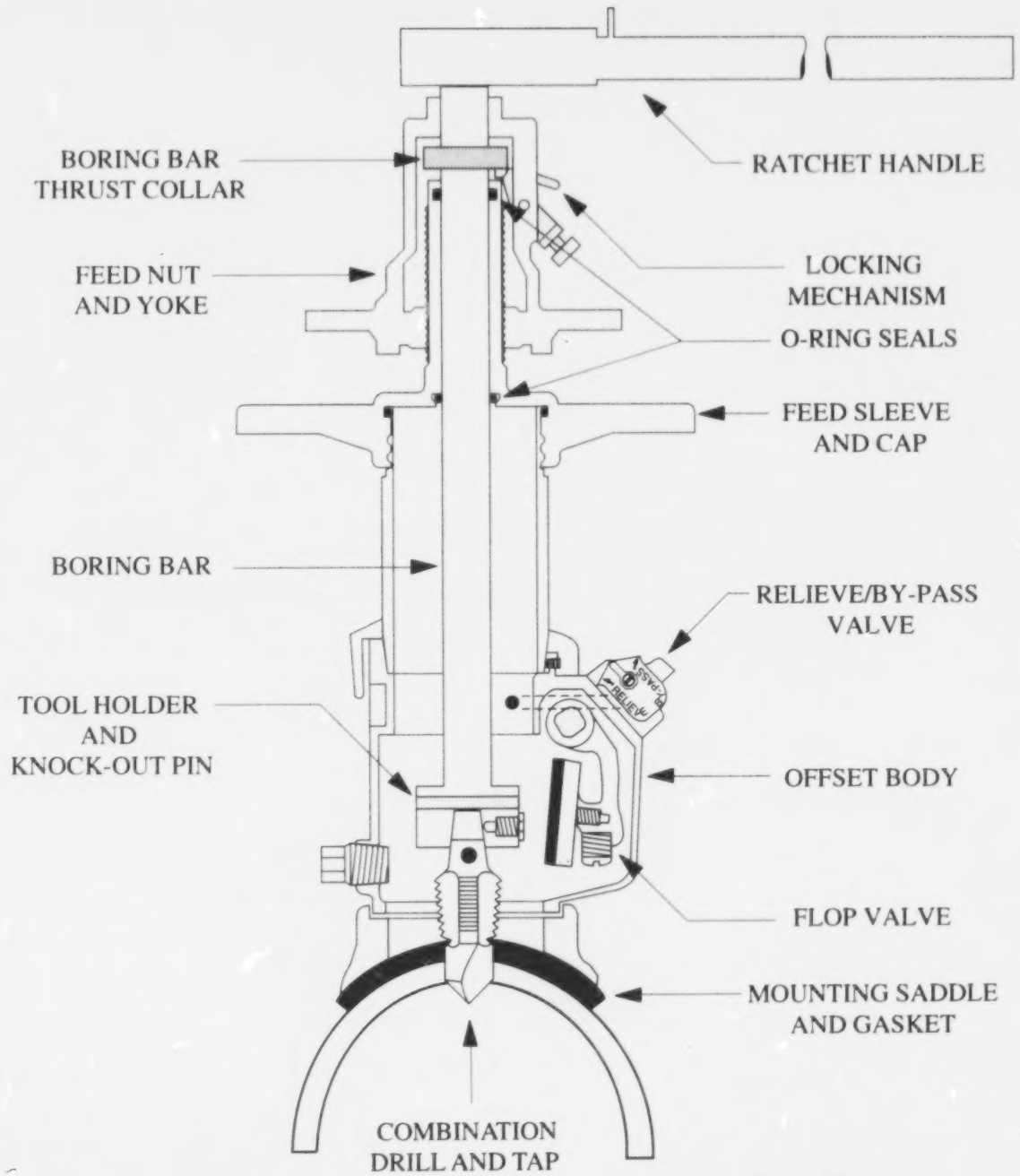

Figure 2-18
Mueller Tapping Machine

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Also check the socket in the end of the boring bar to be sure the bit and screw plug will seat properly.

After tapping, thoroughly clean the entire machine and all tools. Remove all the cuttings from boring and tapping that may remain inside the body, especially in the flop valve recess. If not cleaned out, these chips may rust and interfere with the operation of the flop valve.

CAUTION: Do not tap the body of the machine on a hard surface to remove the chips as this may damage the saddle gasket surface.

Always store the machine, all the accessories and tools in the machine chest to prevent damage and to keep clean. Handle and store all parts carefully to prevent damage to any threads or cutting edges.

Tapping Procedures

To prepare the pipe for tapping, excavate completely around the pipe where the tap is to be made. Clean the pipe thoroughly to be sure the large saddle gasket will seal.

Attach the Machine to the Pipe:

1. Slide the chain under the pipe.
2. Place large saddle gasket on top of the pipe at location of the tap.
3. Place saddle on the large saddle gasket. Each size pipe will require a different size (e.g., 6", 8", etc.) saddle.
4. Place the small saddle gasket in the recess on top of the tapping saddle (Figure 2-17).
5. Place the body and cylinder of the machine on top of the small saddle gasket.
6. Hang the chain hooks and washers in the yoke and attach the chain (Figure 2-19). Attach chain with the ends of the chain hooks flush with the top of the nuts and tighten evenly until hand tight.

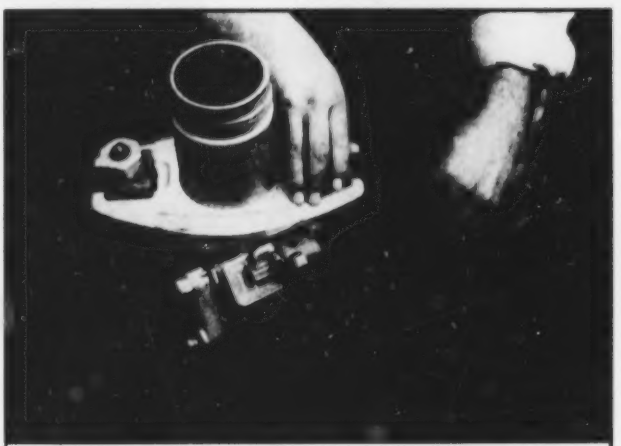

Figure 2-19
Attach the Chain

7. Slide the machine to a 45° angle and tighten nuts evenly using the wrench supplied with the machine. When placing machine on pipe, be sure the BY-PASS valve is on the upper side after rotation (Figure 2-20).

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Figure 2-20
By-Pass Valve

Attach the Tool to the Boring Bar and Assemble the Machine:

1. Insert the shank end of the combined drill and tap into the boring bar socket (Figure 2-21).

Figure 2-21
Boring Bar Socket

2. Tighten tool retaining screw in boring bar using the wrench supplied with the machine (Figure 2-22).

3. Coat the drill end and tap threads with cutting grease.

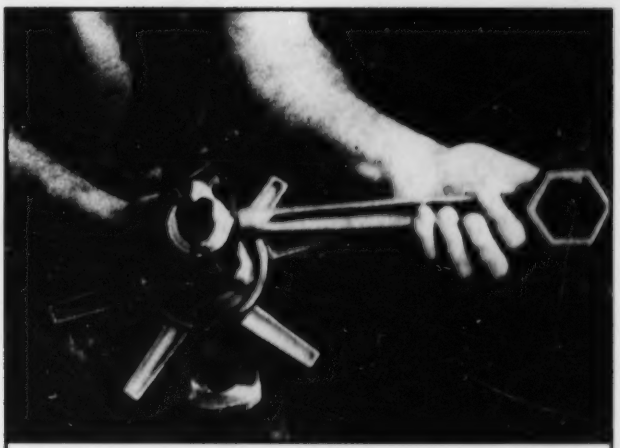

Figure 2-22
Retaining Screw Wrench

4. Move the flop valve to its open position (Figure 2-20).

5. With the boring bar fully retracted, attach boring bar assembly to cylinder of the machine (Figure 2-23).

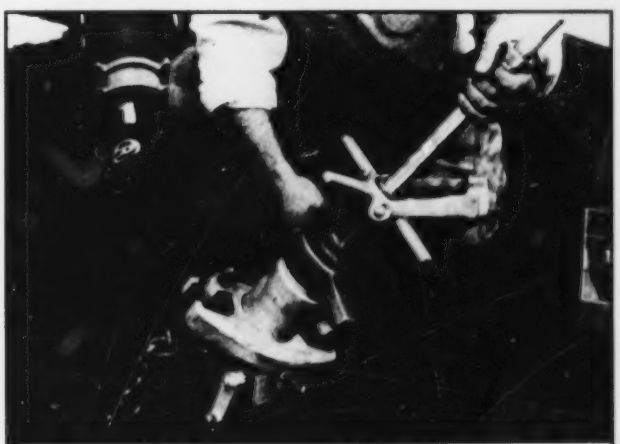

Figure 2-23
Boring Bar Assembly

6. Push the boring bar down until the tool contacts the pipe, and place the feed yoke over the thrust collar on the boring bar (Figure 2-24).

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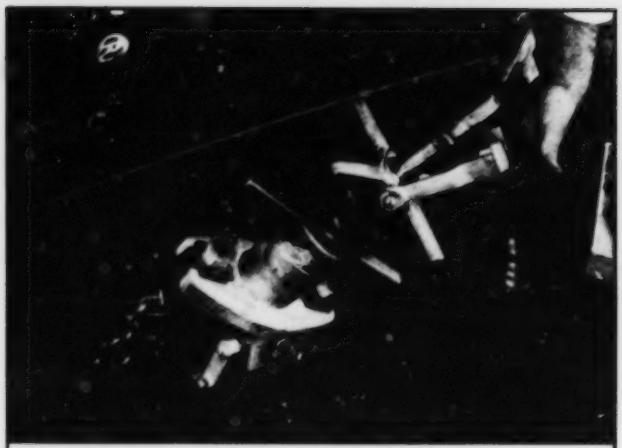

Figure 2-24
Feed Yoke Over Thrust Collar

7. Turn BY-PASS valve to BY-PASS position (Figure 2-20). BY-PASS position is indicated by arrow on the machine casing.

Drill and Tap the Main:

1. Place the ratchet handle on boring bar and set for clockwise rotation.

2. Drilling the main is accomplished by operating the ratchet and turning the feed nut and yoke clockwise a little at a time. The feed nut and yoke should be turned as the boring bar is being turned (Figure 2-25). The boring bar will begin to turn easily when the drill portion of the tool is through the pipe.

3. Continue to rotate the boring bar and feed nut to engage the tapping part of the bit into the main pipe. As tapping begins, rotate the feed nut until the tap is securely into the main, then follow the boring bar with the feed nut without applying pressure to the boring bar.

Figure 2-25
Turn Boring Bar

CAUTION: Applying pressure with the feed nut during tapping will cause stripping of the threads.

4. Continue tapping until tapping line on the boring bar is flush with the top of the feed sleeve part of the cap (Figure 2-26).

Figure 2-26
Boring Bar Flush With Feed Sleeve

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Remove the Drill/Tap from the Boring Bar:

1. Remove the feed yoke from the boring bar by turning the feed nut until the yoke is free.

2. Reverse the ratchet and carefully back the tool out of the tap.

   CAUTION: If the main is under pressure, maintain a downward pressure on the boring bar as the bit is backed out of the main. Once the threads are out of the main, the boring bar will be forced up by water pressure in the main pipe.

3. With the boring bar fully retracted, close the flop valve and turn the BY-PASS valve to the RELIEVE position (Figure 2-27). This will relieve the pressure above the flop valve, and the pressure from the main will hold the flop valve closed.

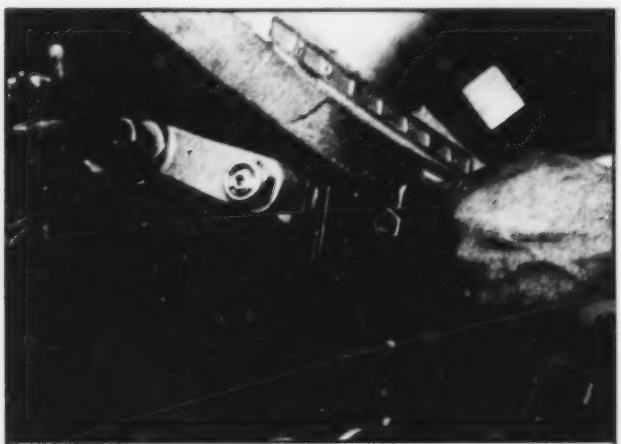

Figure 2-27
By-pass Valve in Relief Position

4. Remove the boring bar assembly from the cylinder of the machine.

5. Remove the drill and tap tool from the boring bar by loosening the retaining screw and tapping the knockout pin (Figure 2-28). Care must be taken not to drop the bit and cause damage to the tip and threads. Be sure to clean the tool after each use.

Figure 2-28
Tap Knockout Pin

Install the Corporation Stop:

1. Insert the shank end of the screw plug into the boring bar socket and tighten retaining screw (Figure 2-29).

2. Screw corporation stop into screw plug. Be sure all purpose threads between the two parts of the screw plug, thread and unthread easily. It is important to check that the corporation stop valve is in the fully closed position as shown in Figure 2-29. Use teflon® tape on the inlet threads.

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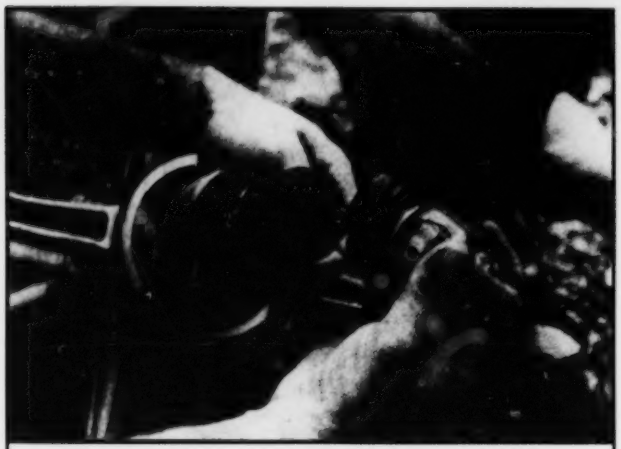

Figure 2-29
Insert Screw Plug into Boring Bar

3. Replace boring bar assembly into cylinder of machine. Keep the boring bar completely retracted. Place ratchet handle on boring bar and set for clockwise rotation.

4. Turn the BY-PASS valve to the BY-PASS position and move flop valve to fully open position as shown in Figure 2-20.

5. Push the boring bar down until the inlet threads of the corporation stop contact the pipe. Rotate the boring bar clockwise to thread the stop into the pipe. Thread the stop into the pipe until it feels solid. *Do not attempt to turn it to its final tightness with the machine.*

6. Reverse the ratchet and strike the handle a sharp blow with the palm of your hand to release the screw plug from the corporation stop. Turn the boring bar until the screw plug is completely free.

7. Turn the BY-PASS valve to the RELIEVE position. This will relieve the water pressure inside the machine (Figure 2-27).

Remove the Machine:

1. Loosen the chain hook nuts, unhook and remove the chain and chain hooks.

2. Remove the machine, saddle, and gaskets.

3. Tighten the corporation stop to final tightness.

4. Replace outlet nut to prevent damage to the threads (Figure 2-30).

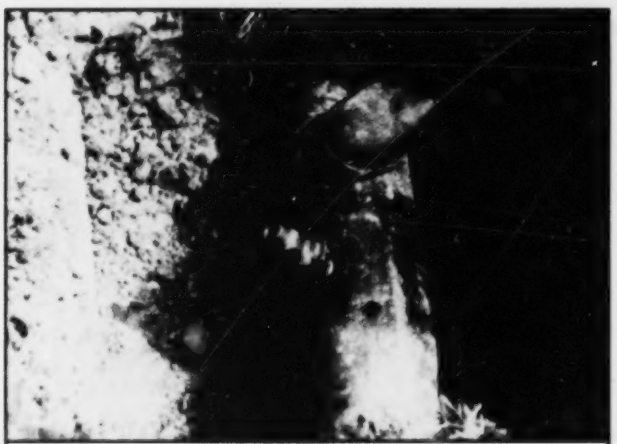

Figure 2-30
Replace Outlet Nut

Once the corporation stop has been placed in the main and the service line connected to the curb stop, the corporation valve is left in the open position and the main is backfilled. A curb stop is a plug valve placed on or

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near the property line and is designed to allow the utility company or homeowner to turn on or off the water to the property. A service box extends to the surface to allow access of the key wrench to turn the valve open or closed.

The corporation stop can also be placed at the high points of a newly installed main to bleed the air out of the line prior to pressure testing.

These valves are often connected with "TYPE K" copper tubing using flared fittings. If the curb stop is not located on the property line, copper tubing must be extended from the curb stop to the property line and the end of the tubing peened. When making water service pipe connections, use teflon® tape on the threads to assure that there will be no leaks as shown in Figure 2-31.

OPERATING THE PORTABLE ALL-PURPOSE SAW

All fuel powered tools shall be stopped while being refueled, serviced, or maintained, and fuel shall be transported, handled, and stored in appropriate containers. When fuel powered tools are used in enclosed spaces, the applicable requirements for concentrations of toxic gases and use of personal protective equipment shall apply. (Refer to OSHA 1926.302(c) Fuel Powered Tools for regulation requirements.)

In sewer and water construction, the portable all-purpose saw is used to cut a variety of different materials, including concrete, ductile iron, steel, and plastic pipes, or wood and steel members used for shoring operations.

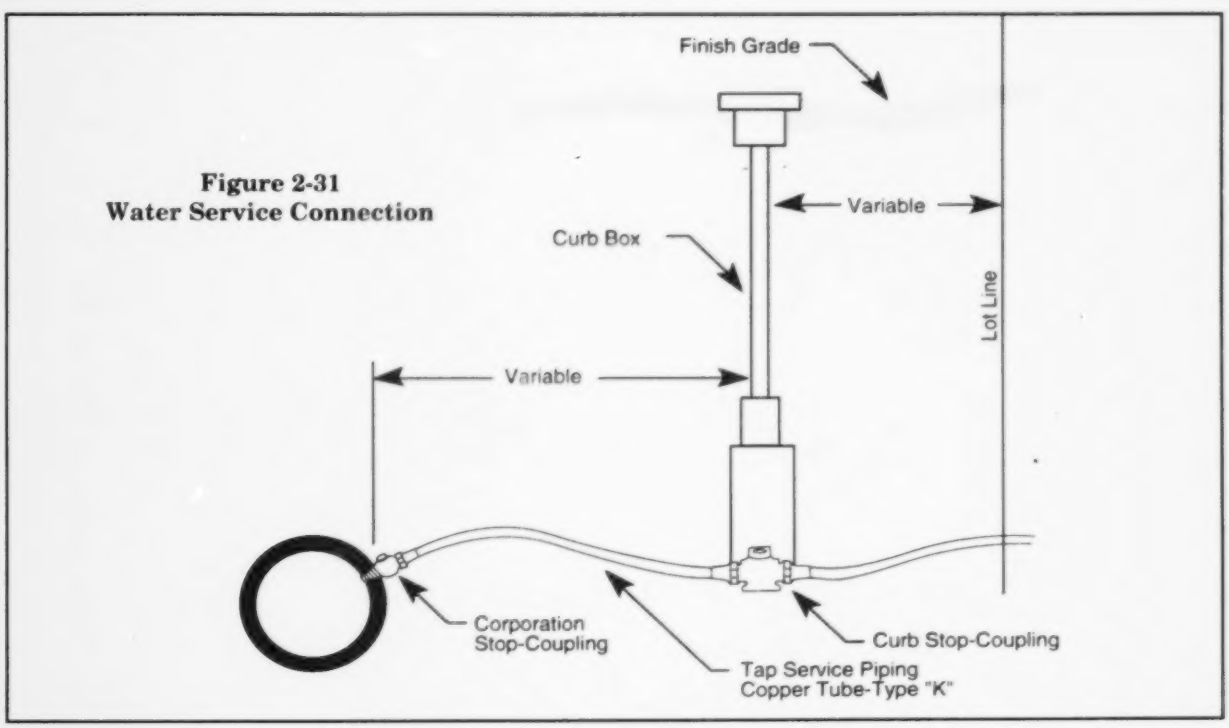

Figure 2-31
Water Service Connection

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In Figure 2-32, a portable all-purpose saw with an abrasive blade is being used for cutting and beveling ductile iron pipe.

Figure 2-32
Portable All-Purpose Saw

Personal protective equipment needed for the safe operation of a portable all-purpose saw should include safety goggles or face shield, ear protection, work gloves, and hard hat. When sawing concrete pipe or other materials that give off dust, a respirator fitted with proper filter cartridges should be used.

All-purpose saws are powered by a two-stroke engine and the fuel used must be mixed with two-cycle engine oil. Be sure the proper mixture, according to the manufacturer's recommendations, is used.

If the gas mixture for the all-purpose saw has been stored for an extended period, be sure to shake it thoroughly before using because the gasoline and oil mixture will begin to separate.

The all-purpose saw uses a variety of different blades. Abrasive blades can be used for cutting concrete, ductile iron, and steel. Diamond blades are used for cutting concrete, but the saw must be fitted with a water attachment. Wood cutting blades are similar to those used on table saws or portable skill saws.

Cutting blades for freehand cutting operations are subjected to particularly high bending and compressive stresses. Top quality blades which match the engine characteristics must be used. Out-of-round or poorly balanced blades increase vibration and reduce the service life of the all-purpose saw. Abrasive blades are heat sensitive and should be stored in a dry place at a constant temperature.

When starting an all-purpose saw, place the saw on the ground, be sure nobody is in the working range of the saw, and the blade is free of all obstructions. A cold engine is started with the choke in the "closed" position, regardless of the time of year, and a warm engine is started with the choke in the "open" position.

Move the ignition switch to the "on" position and set the throttle trigger to the "half throttle" position. Hold the handle bar with one hand and pull the starter grip with the other hand until a definite resistance is felt, then give a strong, brisk pull. Do not allow starter rope to fly back. Keep the choke closed only until the engine fires, then move it to the "open" position. If the engine stops, repeat the procedure. If the choke is left closed after the engine fires, the engine will flood. When the engine is started, "warm" it up by revving briefly to full throttle several times. The engine is stopped by moving the ignition switch to the "stop" position.

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Before starting the saw and making a cut, always adjust the bladeguard so the user is not endangered by particles of the material being cut. Be sure you wear your safety goggles. If cutting metal, be aware of the direction of the sparks so that you do not set yourself or adjacent material on fire.

When cutting, the saw should be operated at full throttle. Let the blade cut freely, and do not use force to push the cutting blade into the work. To achieve a clean and efficient cut, pull the cutting blade across the work or move it forward and backward in the cutting direction. After the cut is complete, the engine should be turned off. Never move from one cutting job to another with the engine running.

When carrying an all-purpose saw, be sure the blade is facing the rear. Always remove the blade when transporting the saw to avoid damage.

When sawing concrete with abrasive blades, a large amount of dust is given off. The air filter's function is to intercept dust and dirt in the combustion air, and thus, reduce wear on engine components. Clogged air filters reduce engine power, increase fuel consumption, and make starting more difficult. Portable all-purpose cut-off saws are equipped with a main filter element and an auxiliary filter. The main filter element should be changed as soon as engine power begins to drop off. The auxiliary filter protects the engine if the main filter element becomes damaged. In high dust conditions, the air filter should be checked every half hour to prevent poor engine performance.

POLYETHYLENE PIPE FUSION TECHNIQUES

Before starting a polyethylene fusion operation, two details must be reviewed. First, the fusing machine operator must know the correct heating temperature and second, the operator must know the amount of time the pipe ends must be heated to obtain an acceptable joint.

The heating time and temperature is determined by the wall thickness of the pipe to be fused. Polyethylene pipe manufacturers provide a chart with correct heating temperatures for each pipe size and wall thickness.

Heating time can be determined by watching for the proper melt pattern on the pipe ends when they are pressed against the heating element. A melt bead will form as the pipe ends reach the correct fusing temperature. The size of the melt bead will vary with the pipe size, usually about 1/16" while against the heater plate and up to 1/8" when the pipe ends are fused together.

Fusion Procedure

Before starting fusing operations, inspect fusing machine to be sure it is in good operating condition. Check the cords on the facer and the heater to be sure they are not damaged and are properly grounded.

If possible, set up the fusing machine in a clean, dry area. Plug in the double edge facer and the heating plate. Be sure heating plate reaches the correct temperature before using.

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Proper vertical and horizontal alignment is necessary to make an acceptable fused joint.

1. Horizontal alignment can be achieved by sighting down the two lengths of pipe to be fused.

2. Vertical alignment can be achieved by using blocks to raise the pipe ends to the same height as the fusing machine (Figure 2-33).

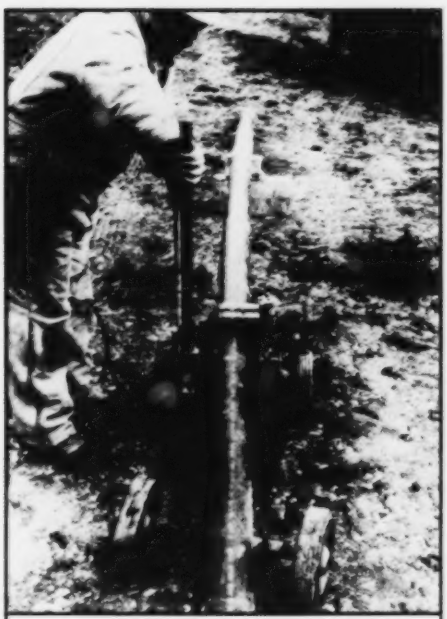

Figure 2-33
Blocks at Pipe End

3. When placing the pipe in the fusing machine, be sure the pipe ends extend about 1 1/2" inside the alignment jaws (Figure 2-34).

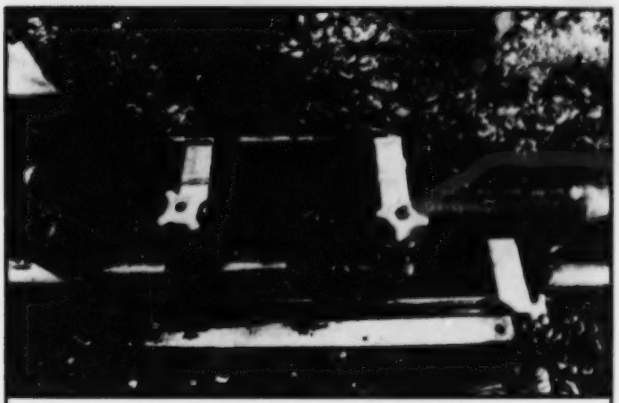

Figure 2-34
Pipe Ends Past Jaws

4. Secure the pipe by tightening the alignment jaw retainer nuts (Figure 2-35).

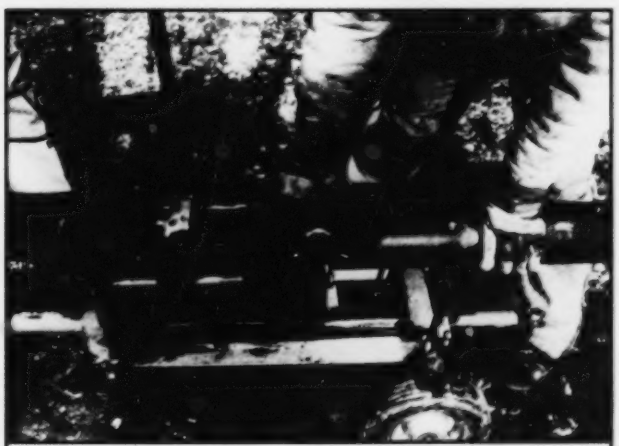

Figure 2-35
Tighten Alignment Jaw Nuts

5. Bring the ends of the pipe together to check for proper alignments.

6. Move the pipe ends apart and place the facer on the machine (Figure 2-36) and keep cutting until long continuous ribbons are cut from both pipe faces.

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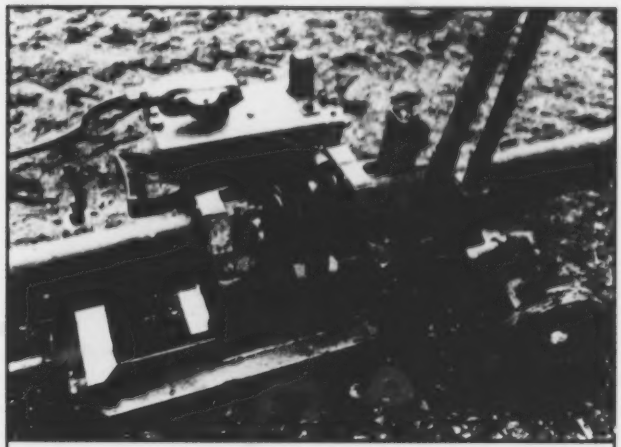

Figure 2-36
Place Facer on Machine

7. Remove facer and move the pipe ends together and check for a smooth fit. If the pipe ends do not butt together perfectly, reface each end until they do (Figure 2-37).

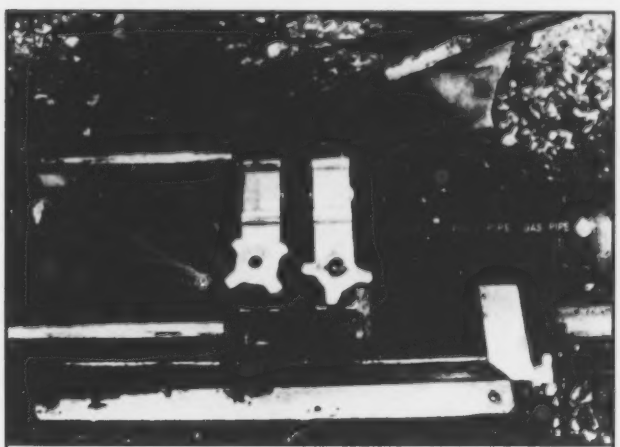

Figure 2-37
Check for a Smooth Fit

8. Use a clean, lint-free cloth to remove any shavings from the inside and ends of the pipe (Figure 2-38). Do not remove shavings with your hands because the oil on your skin will contaminate the fusion.

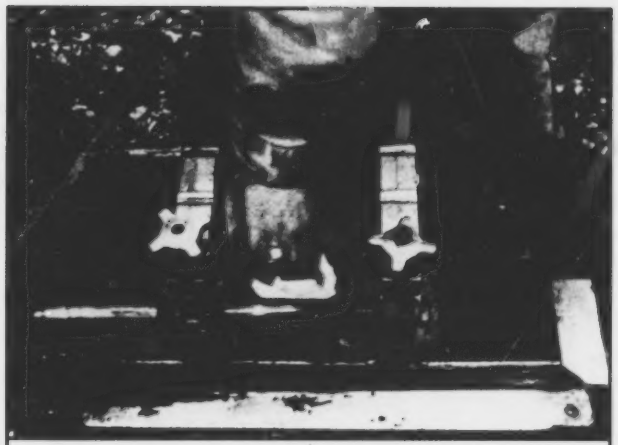

Figure 2-38
Clean Ends with Lint-Free Cloth

9. Place the heating plate on the machine (Figure 2-39) and bring the pipe ends into contact with it (Figure 2-40).

Figure 2-39
Heating Plate

Do not apply pressure while the pipe ends are heating. As the ends heat up, watch the melt bead begin to form. When the bead has formed to approximately 1/16" all around the pipe end, move the pipe ends away from the heating plate and remove it.

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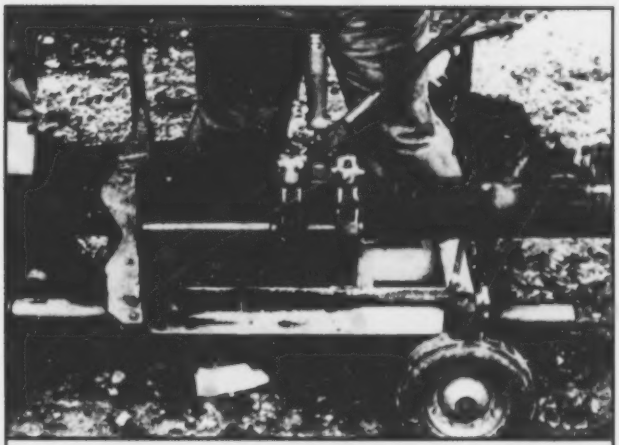

Figure 2-40
Pipe Ends Contact Heating Plate

10. Bring the pipe ends together immediately and apply a slight but steady pressure. This will form a double bead as shown in Figure 2-41. Do not apply too much pressure. Too much pressure will squeeze out all of the melted material and will form a cold brittle joint.

11. Allow the fusion joint to cool until you can comfortably hold your finger on it. Remove pipe from fusing machine by releasing the alignment jaws.

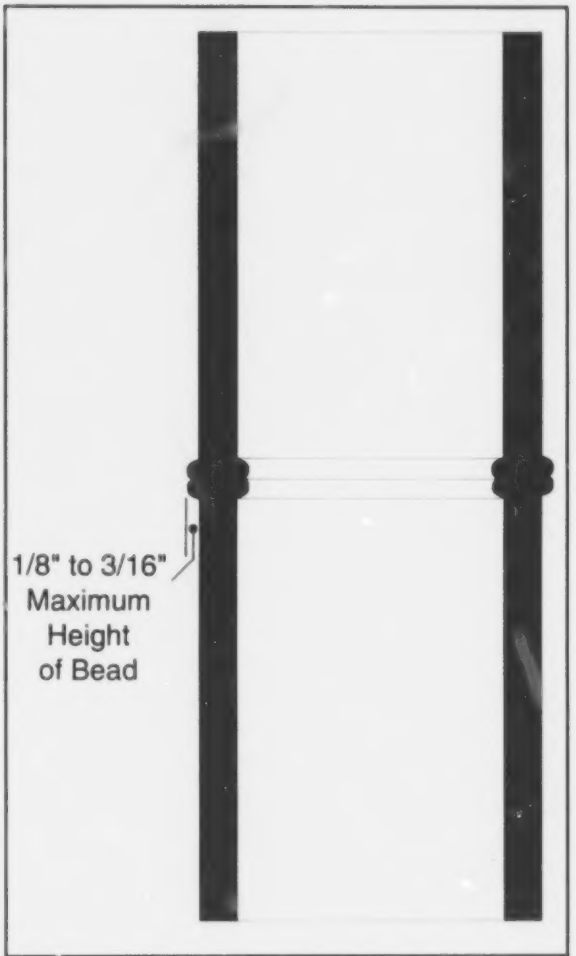

Figure 2-41
Double Bead

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SECTION II ASSIGNMENT SHEETS

Describe the responsibilities of each person:

The lead pipelayer _____

_____

_____

The top man _____

_____

_____

The tail pipelayer _____

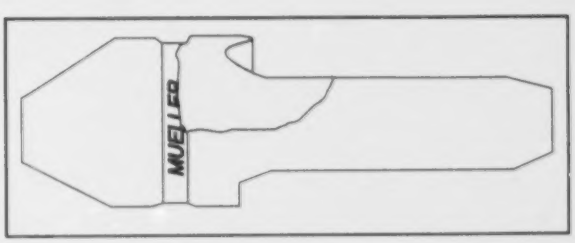
_____

_____

Identify each of the following illustrations:

1._____

2._____



3._____

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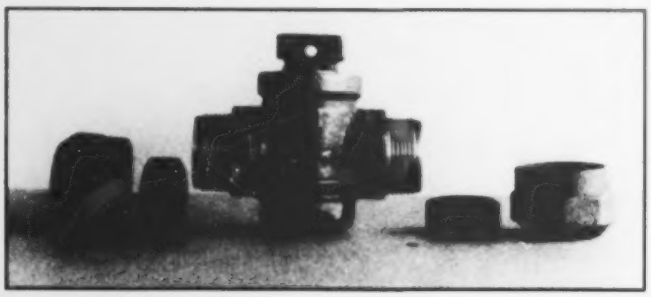
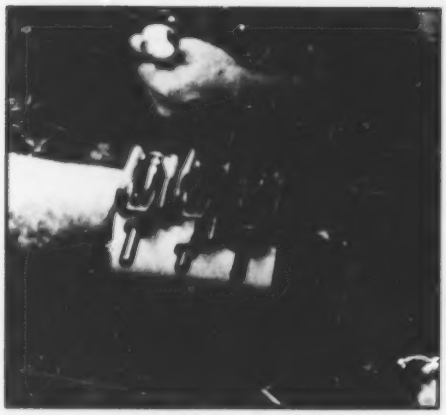
4. _____



5. _____



6. _____

Answer the Following Questions:

1. Does a mechanical joint require lubrication? _____
2. You should always tighten the bolts _____ when tightening a mechanical joint.
3. Before inserting a pup into a tyton joint, the cut should be _____.
4. A fire line is usually required to be _____ to the main.
5. After a previously bolted fitting is lowered into the excavation and bolted into place, the pipelayers should always _____ the fittings.
6. What is a standard joint length of Ductile Iron Pipe? _____
7. During back-fill of a fire hydrant and valve riser, both fittings must be constantly checked for _____ .
8. When should a main line gate valve be opened quickly? _____
9. What is a common test pressure and duration for main lines? _____

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10. Before testing, the line should be _____.

11. During a pressure test, the pressure continues to bleed down slowly, you probably have _____ in the line.

12. To assist in pressure testing, bleed valves should be placed at the_____ _____ in the line.

13. If a stop and waste valve is designed to be used at the curb on every service installation, the arrow on the valve should point _____the building.

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NOTES:

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SECTION III: UTILITY LINE AND GRADE

Page 70	Terms and Definitions
Page 72	Construction Measurements
Page 75	Measurement Systems
Page 87	Stationing System
Page 89	Squaring Principles
Page 90	Slope Expressions
Page 95	Cut Sheets
Page 97	Elevation Control
Page 101	Section III Assignment Sheets

Trainee Objectives

Define the terms:

Level	Offset	Story Pole
Plumb	Reference Point	Slope Ratio
Percent of Grade	Station	
Rate per Foot	Square	

Use different measurement systems, including the U.S. Standard, Decimal, and Metric Systems.

Convert between measurement systems, including the U.S. Standard, Decimal, and Metric Systems.

Convert between various units of measure from the multiplier table in Appendix A.

Describe common referencing methods.

Calculate distances using the stationing system.

Use squaring principles to set offset stakes.

Calculate elevations and elevation changes using a rate per foot or percentage of slope.

Calculate elevations and cut distances for grade sheets.

Correctly set-up and demonstrate the use of an offset batter board system.

Correctly set-up and demonstrate the use of a level/transit.

Correctly set-up and demonstrate the use of a pipe laser in pipe, in a manhole, and above the pipe.

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TERMS AND DEFINITIONS

Bench Mark: A surveyors stake or mark at a known elevation. Bench marks are used as reference points to establish other known elevations or control points. These control points are used to establish grade for the construction of sewers.

Center Line: The exact center of a structure; in sewer construction used as ℄ of pipe or ℄ of a manhole.

Cut: The vertical distance from the top of an offset stake to the invert or flowline of a pipe.

Cut Sheet: A printed form furnished by the engineer giving the computed cut or elevation from the offset stake to the pipe invert at specific stations. Cuts may also be found on witness stakes next to the offset hubs.

Grade: The slope of a line in reference to a horizontal plane.

Height of Instrument: (HI) The distance measured vertically from center line of transit to a reference point, such as a bench mark, a pipe flowline, or a laser.

Horizontal: Is parallel to the horizon or level. Horizontal measurements are usually called stations.

Level: Parallel with the plane of the horizon: HORIZONTAL, also, a device for establishing a horizontal line or plane by means of a bubble in a liquid that shows adjustment to the horizontal by movement to the center of a slightly bowed glass tube.

Offset: The distance measured from a pipe to offset stakes. On witness stakes, offset is usually written with the offset distance inside a circle. Stakes are purposely set back on a construction base line, out of the way of the construction processes, so the staking is not destroyed and the work proceeds uninterrupted.

Percent of grade: The amount of slope of a pipe from one point to another. This slope can also be expressed as rate per foot.

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Plumb:	Straight up or down: VERTICAL, also, exactly vertical or true.
Rise:	The difference in feet from one known point to another known point.
Rate Per Foot: (RT./FT.)	The actual amount of vertical rise or fall in a horizontal distance of one foot.
Reference Point: (RP)	A point of known alignment and elevation. Usually used to describe another point or location.
Slip Joints:	Slip joints have factory installed rubber gaskets. These joints are also called push-on joints because they are pushed together.
Slope Ratio	A horizontal to vertical relationship with the horizontal expressed first and the vertical always expressed as one.
Stake Elevation:	The height of a stake in relationship to sea level. Used to determine cut or fill to flowline of pipe.
Station:	At right angles; also forming a right angle; also having four equal sides and four right angles.
Story Pole:	A horizontal distance of 100 feet or an actual location on a project center or baseline; also to assign to or set in a station or position.
Square:	A job constructed piece of lumber used to indicate various elevations or layouts.
USGS:	(United States Geological Survey) A survey made by the federal government to establish exact coordinates and elevations above the mean sea level throughout the United States.
Vertical:	Is perpendicular to the horizon or plumb. Vertical measurements are usually called grades or elevations.

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CONSTRUCTION MEASUREMENTS

Almost without exception, all construction measurements are accomplished either level or plumb.

To make length measurements, you could use a tape measure, rag tape, or surveyor's chain (metal tape).

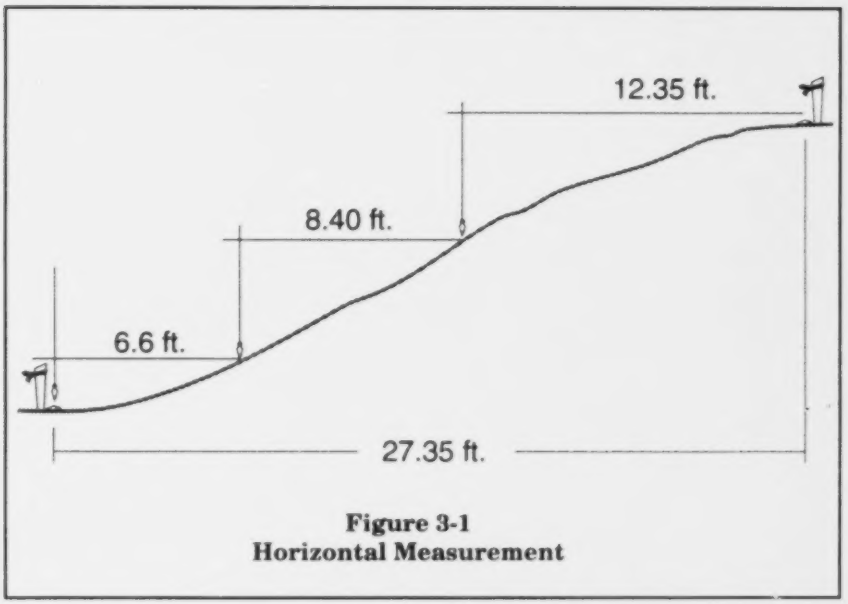

Figure 3-1
Horizontal Measurement

Whenever making a length measurement, care must be taken to ensure the tape is without sag, held level, and in line with the points to be measured. If the tape cannot be held on the points to be measured due to obstructions or sloped ground as shown in Figure 3-1, the tape must still be held level and the distance transferred from the tape to the ground vertically. This can be accomplished by using a plumb bob or by dropping an object, such as a rock or stake.

Vertical measurements are usually accomplished with the use of a grade rod or story pole and an optical leveling

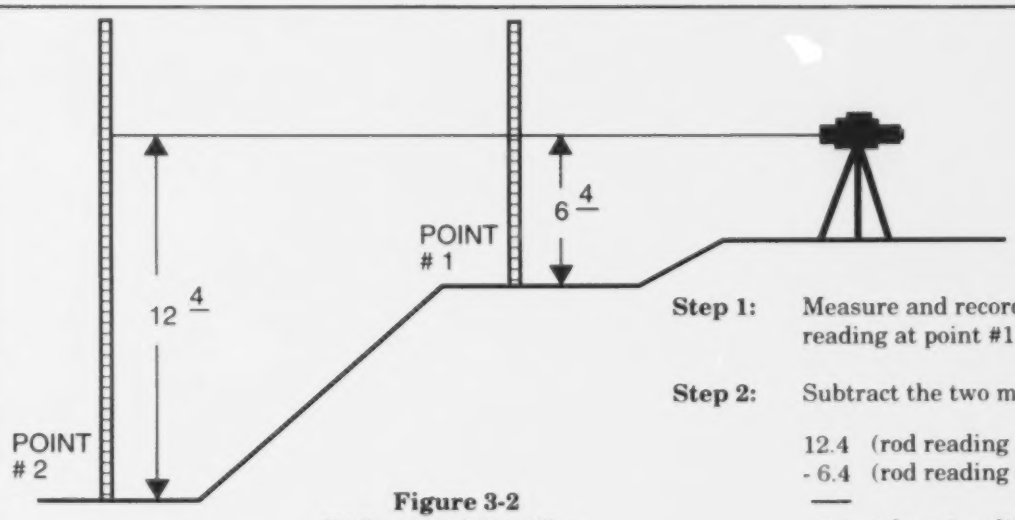

Figure 3-2
Differential Leveling

Step 1: Measure and record the rod reading at point #1 and #2

Step 2: Subtract the two measurements

12.4 (rod reading at point #2)
- 6.4 (rod reading at point #1)

6.0 (elevation difference in feet)

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instrument, such as a level or eye level. The process is called differential leveling and involves the subtraction of one measurement from another. For example, Figure 3-2 depicts a measurement to two points from the same elevation.

Common Referencing Methods

In construction, the term "reference point" indicates a stake, nail, or other mark that is in a known location, horizontally and vertically. It is used to describe the distance horizontally and vertically to another point, such as "flow line" or "top of pipe."

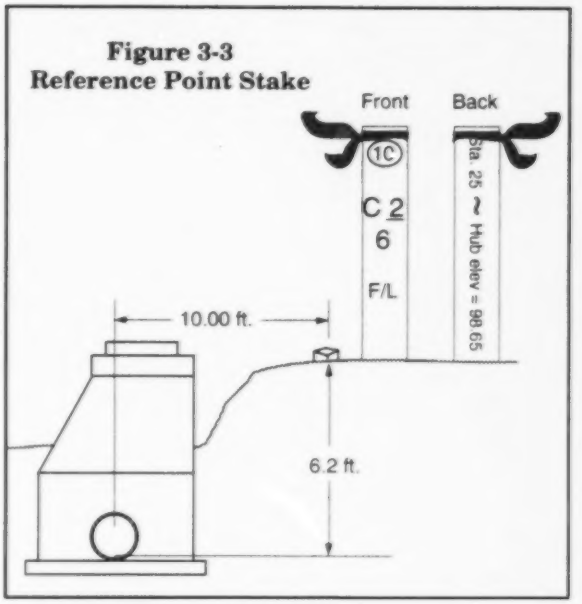
Due to the possibility of error or confusion, a decimal point is seldom used when marking on a lath or stake. Instead, the decimal point is represented as a slash mark under the decimal portion of the number.

A horizontal distance or offset is usually indicated by a number in a circle or a number under the letters "O.S."

A vertical distance will usually be written as a "C" or "F" indicating CUT or FILL. Do not assume that a cut or fill distance always indicates the true amount of material to be placed or excavated. The symbols are only to indicate a vertical distance and direction.

In most cases, the back side of a reference point stake will note the station location of the referenced point; it may also give the above sea level elevation of the hub or utility. Figure 3-3 depicts a sample reference point stake for a sewer line installation. Note that the vertical

Figure 3-3
Reference Point Stake



"Cut" distance is specified to the flow line of the pipe.

Measuring From Offset Reference Stakes

In order to ensure that you measure in the correct direction from an offset reference stake, the referencing will usually be designed using either an In-line method or a Right-angle method.

In-line referencing will have two stakes set in line with each other and the object that is referenced. Figure 3-4 shows in-

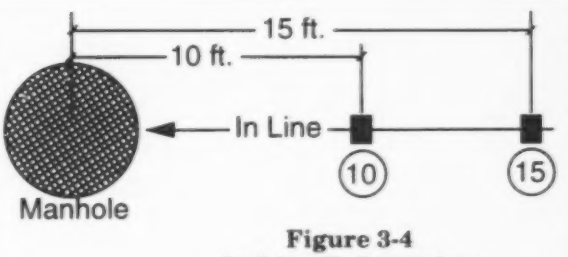


Figure 3-4
In-Line Referencing

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line referencing. Note how both stakes are set to reference one point or object.

Right-angle referencing uses a stake line set parallel to the utility and the offset distance should be measured at a right angle to the stake line. Figure 3-5 shows a ten foot offset line to a water utility installation.

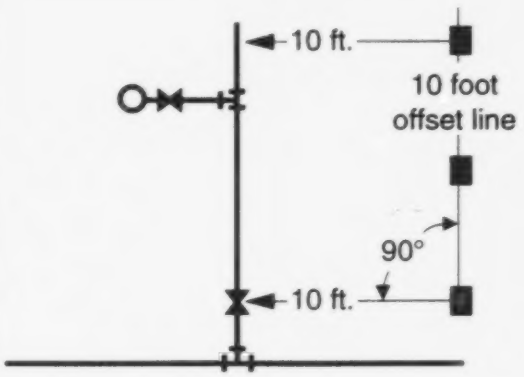

Figure 3-5
Right- AngleReferencing

Other Types of Referencing

There are many methods to reference a place or location. These range from in-line and right-angle referencing to a form of referencing called swing ties.

The swing tie method of referencing is an excellent way of marking the location of an item or place that may need to be relocated at a later time. For this reason, it is used by surveyors and engineers frequently.

An example of swing tie referencing is depicted in Figure 3-6. In this case, a manhole was previously buried to allow the roadway finishing crew to conduct grading operations over it.

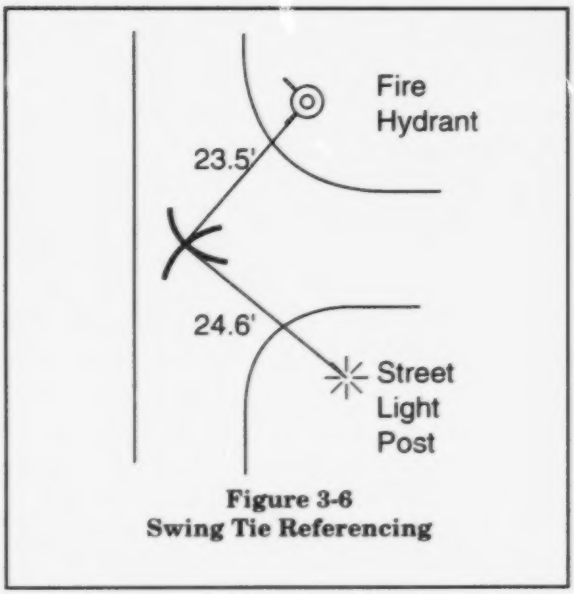

Figure 3-6
Swing Tie Referencing

Prior to burial, two distances to fixed objects were measured and noted on the blue prints or in a job notebook.

After the work is accomplished, the two distances can be measured using two tapes or, if only one tape is used, an arc can be marked on the ground from each point.

Where the arcs cross is the same point as was originally measured.

When you use swing tie referencing, try not to set the referencing points directly across from each other. This can cause the arcs to touch over a large distance or to cross twice. It is best to try for a 30° to 45° angle between the measured points.

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MEASUREMENT SYSTEMS

Working with Fractions

The following example shows which number is the numerator and which is the denominator in a fraction. The numerator is the number on top and the denominator is the number on the bottom of the fraction.

$$\frac{1}{2}\ \begin{matrix}\text{Numerator}\\ \text{Denominator}\end{matrix}$$

To add or subtract fractions, you must work with the same denominator, or in arithmetic terms, "like fractions." If the fractions you are going to work with are already expressed as like fractions, then you can simply add or subtract the numerators and reduce the fraction to its lowest term. The following example shows the addition of like fractions.

$$\frac{1}{8} + \frac{3}{8} = \frac{4}{8} = \frac{1}{2}$$

The addition of the numerators of 1 and 3 equals 4. When the fraction is expressed as 4/8, both the numerator and the denominator are evenly divisible by 4. This indicates that the fraction is not reduced to its lowest term. Divide both by 4 and the reduced fraction is 1/2.

To subtract like fractions, use the same procedure. The subtraction of the numerators of 3 and 1 equals 2.

When the fraction is expressed as 2/8, both the numerator and the denominator are evenly divisible. This indicates that the fraction is not reduced to its lowest term. Divide both by 2 and the reduced fraction is 1/4.

$$\frac{3}{8} - \frac{1}{8} = \frac{2}{8} = \frac{1}{4}$$

When the fractions are not expressed with the same denominator, you must form like fractions. To form like fractions, multiply the larger fraction by whatever number is needed to form a common denominator. In the folowing example, you are asked to add the fractions 1/2 and 1/8.

$$\frac{1}{2} + \frac{1}{8} = \frac{?}{?}$$

To form the common denominator, we will multiply the larger fraction (1/2) by a number that will form a common denominator of 8 (which is 4).

$$\frac{1}{2} \times \frac{4}{4} = \frac{4}{8}$$

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Once we have formed the common denominator, we can add as we did previously. Since the sum is not evenly divisible, this fraction is already expressed in the lowest term.

$$\frac{4}{8} + \frac{1}{8} = \frac{5}{8}$$

You can form a common denominator for any set of fractions; however, you must **multiply the numerator by the same number as the denominator.** Subtraction of fractions can be worked using the same procedure.

Exercise 1: Add or subtract the following measurements.

1. 1/8" + 5/8" =

2. 1/4" + 3/4" =

3. 3/8" + 3/4" =

4. 1/2" + 3/8" =

5. 1 5/8" + 1 1/8" =

6. 3 3/4" + 2 1/4" =

7. 3/4" - 1/4" =

8. 5/8" - 3/8" =

9. 7/8" - 1/4" =

10. 1 3/4" - 1 1/8" =

11. 2 7/8" - 1 1/2" =

12. 3 5/16" - 1 3/4" =

Working with Decimal Numbers

The rules for addition, subtraction, multiplication, and division of decimal numbers are reviewed in the following examples. For addition and subtraction, the decimal points must be lined up.

$$\begin{array}{r} 1.1 \\ +\ 8.2 \\ \hline 9.3 \end{array} \qquad \begin{array}{r} 8.2 \\ -\ 1.1 \\ \hline 7.1 \end{array}$$

For multiplication, count the total number of digits to the right of the decimal points in the problem, and move that number to the left in the answer. In the following example, there are a total of four places to the left of the decimal point in the problem, so you count four decimal places to the left in your final answer.

$$\begin{array}{rl} 15.30 & \text{two places} \\ \times 1.25 & \text{two places} \\ \hline \\ 7650 & \\ 30600 & \\ 153000 & \\ \hline \\ 19.1250 & \text{four places} \end{array}$$

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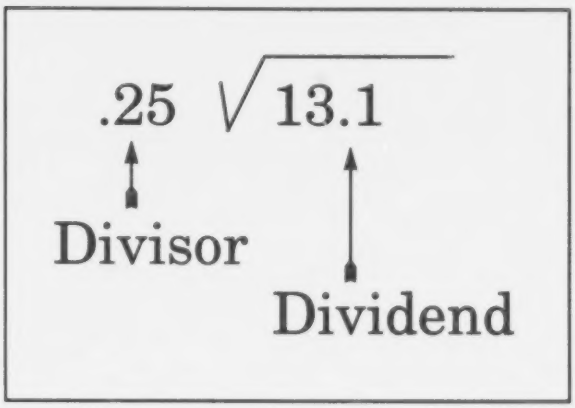
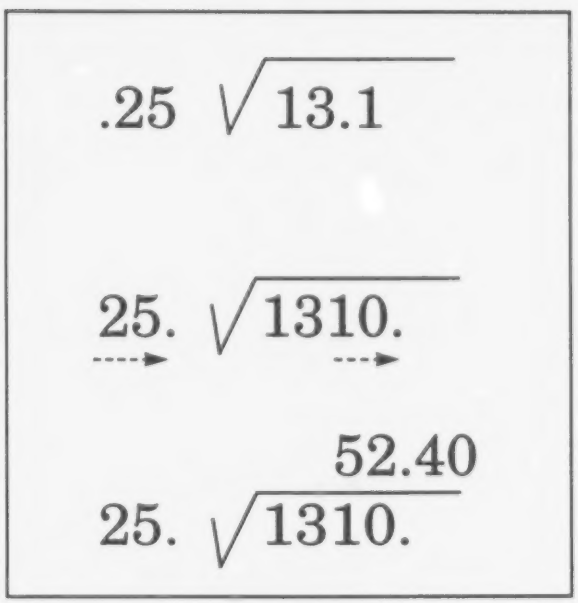
In division, the number to be divided is called the "dividend," and the number that is doing the dividing is called the "divisor."



To divide with a decimal, move the decimal point to the right in the divisor to form a whole number (.25 becomes 25.0). Move the decimal point in the dividend (13.1) the same number of places and add zeros when needed (13.1 becomes 1310.0) Divide as normal and move the decimal point straight up in the answer.



Exercise 2: Work the following problems without a calculator and round the answers to three decimal places.

Add the following figures. Be sure that the decimal point is in the correct place.

1. 5.66 + 20.75 + 16.03 =

2. 10.95 + 3.06 + 9.47 =

3. 3.958 + 24.976 + 21.954 =

Subtract the following:

4. 5.13 - 4.01 =

5. 12.28 - 6.67 =

6. 106.29 - 0.66 =

Multiply the following:

7. 5.16 x 1.5 =

8. 3.1 x .05 =

9. 1.3 x 2.51 =

Divide the following and place the decimal point in the proper place:

10. 505.5 ÷ 50. =

11. 50.9 ÷ 15. =

12. 56.7 ÷ 2.5 =

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Exercise 3: Use a calculator to work the following multiplication and division problems. Round your answers two decimal places.

Multiplication

1. 1034.67 x 201 =
2. .51 x 21 =
3. 1.21 x .09 =
4. 6.18 x 1.16 =
5. 635.5 x 1.01 =
6. 195.5 x 10.3 =
7. 64.555 x .50 =

Division

8. 5826 ÷ 6.5 =
9. .25 ÷ .5 =
10. 4.58 ÷ 1.5 =
11. 100.13 ÷ .25 =
12. 341.4 ÷ 2.7 =
13. .369 ÷ .80 =
14. 5694.45 ÷ 54.4 =

Standard Rules and Measurements

A foot on the U.S. Standard Six Foot Rule is composed of twelve basic parts called inches. Each inch is divided into fractions that split the inch in half (1/2"), then into quarters (1/4"), then into eighths (1/8"), and finally into sixteenths (1/16").

A foot on the Engineer's Six Foot Rule is composed of ten basic parts called tenths. Each tenth is further divided into ten smaller portions called hundredths. A foot has 100 hundredths (10 tenths times 10 hundredths).

Think of a dollar; it is made up of one hundred cents or pennies. The Engineer's Rule with a foot broken down into one hundred equal parts can easily be compared to a one dollar bill in our money system. The Engineer's Rule has one hundred hundredths to the foot. Using this frame of reference, the Engineer's Rule is easily learned.

Look at the U.S. Standard side of the rule. Notice that the inches are denoted by large black numerals, and starting with the one foot mark, the feet are designated by large red numerals and a large letter "F"; "2F" equals the two foot mark.

Between feet, starting with the one foot mark, small red numerals precede each inch mark in that particular foot, so one can find a reading of 2' 10".

Look at the Engineer's side of the rule. You will notice that the tenths are denoted by large black numerals and starting with the one foot mark, the feet are designated by large red numerals, and a large letter "F"; "2F" equals the two foot mark.

Between feet, starting with the one foot mark, small red numerals precede each tenth mark in that particular foot, so one can find a reading of 2.30' (two and three tenths or two and 30 hundredths foot).

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It is easy to change inches and parts of inches to tenths and hundredths or vice versa. Using the Engineer's Rule, you hold your reading on one side and turn the rule over and without any mathematical trouble, the change is made. For example, one foot six inches (1'-6") on the U. S. Standard side equals one foot and five tenths (1.50') on the Engineer's Rule side.

Now turn the rule over to the Engineer's side. The first thing you see is the two bold red lines running parallel the length of the rule. These lines help you to prevent error and mix-ups by designating this side of the rule as the Engineer's Rule.

Care of the Rule

Take out a six foot Engineer's Rule, unfold it carefully, six inches by six inches. Take care of the rule, fold it after each use. When folding after use, back it on itself, six inches by six inches. Keep it clean and take it out of your pocket before sitting down in a truck or car.

Rules to remember when reading an Engineer's Rule:

1. First locate feet.
2. Find tenths.
3. Count hundredths.

Any reading ending in zero is either tenths of feet (.50'), feet (4.00'), or feet and tenths (4.80'). Any reading ending in a numeral has to be read as hundredths of one foot (0.79') or as feet and hundredths (3.79').

Exercise 4: Measure from point to point on the following page, using both sides of the rule. Record your measurements on this page. Round to the nearest 0.01 feet.

Standard Rule

A-B	_____	F-G	_____
B-C	_____	G-H	_____
C-D	_____	H-I	_____
D-E	_____	I-J	_____
E-F	_____	J-K	_____

Engineer's Rule

A-B	_____	F-G	_____
B-C	_____	G-H	_____
C-D	_____	H-I	_____
D-E	_____	I-J	_____
E-F	_____	J-K	_____

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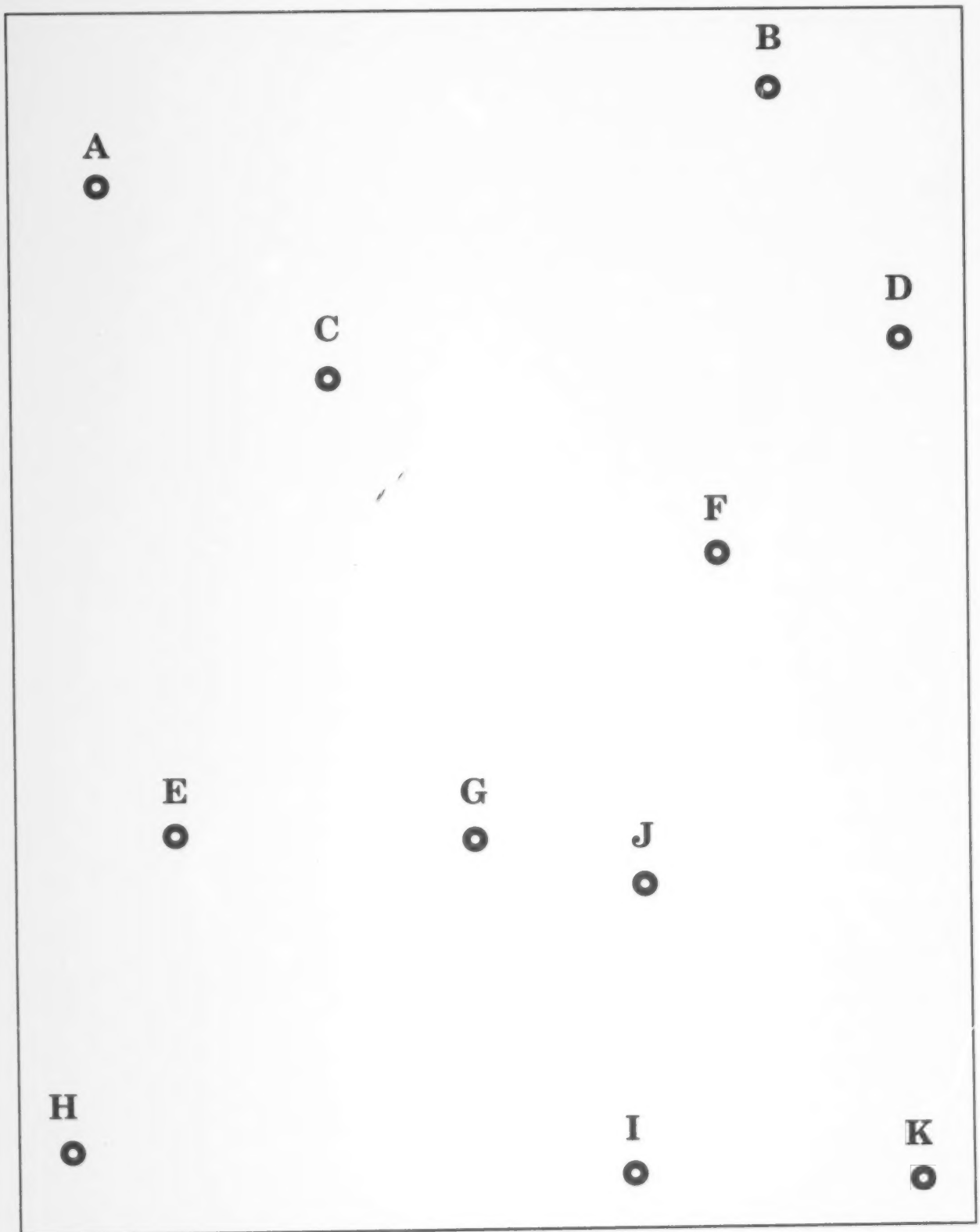

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Table 3-1: Inch to Decimal Conversion

Inches	=	Decimal Feet
1"		.08'
2"		.17'
*3"		.25'
4"		.33'
5"		.42'
*6"		.50'
7"		.58'
8"		.67'
*9"		.75'
10"		.83'
11"		.92'
*12"		1.00'
13"		1.08'

minus .25 - .08 = .17'

plus .25 + .08 = .33'

minus .50 + .08 = .42'

plus .50 - .08 = .42'

minus .75 - .08 = .67'

plus .75 + .08 = .83'

minus 1.00 - .08 = .92'

plus 1.00 + .08 = 1.08'

This table explains how to convert from inch to decimal without referring to a chart. One inch is actually 1/12th of a foot. This equals .0833 feet which becomes .08' when it is rounded. Two inches is actually .0833' x 2, which is .1667 feet. As you can see in the chart when this number is rounded, it becomes .17 feet. Each number with an asterisk (*) is a marker that helps you to figure out the decimal value for each inch above or below the marker. For instance, 9 inches is three quarters of a foot or .75 feet. To get the decimal amount for 8 inches, subtract .08 from .75 feet, giving you .67 feet. To figure out 10 inches add .08 to .75 feet. Memorization is also another alternative to this method.

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Table 3-2: U.S. Standard to Decimal Conversion

Standard Measurement	=	Decimal Measurement
1/8"		0.01'
1/4"		0.02'
3/8"		0.03'
1/2"		0.04'
5/8"		0.05'
3/4"		0.06'
7/8"		0.07'
1"		0.08'
2"		0.17'
3"		0.25'
4"		0.33'
5"		0.42'
6"		0.50'
7"		0.58'
8"		0.67'
9"		0.75'
10"		0.83'
11"		0.92'
12"		1.00'
1'-3"		1.25'
1'-4"		1.33'
1'-6"		1.50'
1'-9"		1.75'

The six basic conversion parts to remember:

1/8"	0.01'
1"	0.08'
3"	0.25'
6"	0.50'
9"	0.75'
12"	1.00'

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Exercise 5: Use the conversion table (Table 3-2) to convert the following U.S. Standard expressions to decimal expressions:

1. 1/8" =
2. 1" =
3. 5" =
4. 11" =
5. 7/8" =
6. 8" =
7. 1/2" =
8. 3" =
9. 3/8" =
10. 9" =
11. 6" =
12. 3/4" =
13. 12" =
14. 2" =
15. 1/4" =
16. 7" =
17. 10" =
18. 5/8" =

Converting Between the U.S. Standard and the Decimal System

There are several ways to convert between measuring systems. One of the easiest methods to convert between the Decimal and U.S. Standard measuring systems is to form an equivalent ratio of 1/8" = 0.01'.

By forming this ratio, you can change a fraction to eighths and express that same number of eighths as hundredths or vice versa.

The ratio of 1/8" = 0.01' is not exact. Due to rounding 1/8" actually equals 0.01333 or one and a third hundredths. This rounding can be accounted for and will not cause an error until you start converting more than eight-eighths at one time.

To eliminate the rounding error, do not convert more than eight-eighths at one time. Instead, convert the closest whole inch equivalent first, then change the remainder to eighths and convert that to hundredths. To complete the conversion, add the equivalent of the closest whole inch and the remainder together.

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The examples shown below demonstrate this two-step process:

Examples: Change the inches to a decimal of a foot, then the fraction to decimal of a foot and add the two together.

a. 18 3/8" = ?

18" = 1.50'
3/8" = + .03'
1.53'

b. 11 5/8" = ?

11" = .92'
5/8" = + .05'
.97'

c. 2 3/4" = ?

2" = .17'
3/4" = + .06'
.23'

d. 16 1/4" = ?

16 " = 1.33'
1/4" = + .02'
1.35'

Exercise 6: Convert the following to feet, tenths, and hundredths.

1. 2 1/2" =

2. 5 7/8" =

3. 7 3/8" =

4. 8 3/4" =

5. 3 1/2" =

6. 33 3/4" =

7. 27 1/4" =

8. 75 1/2" =

9. 4 1/4" =

10. 3 5/8" =

11. 6 3/4" =

12. 9 1/2" =

Converting Between the Decimal and the U.S. Standard System

To convert from the decimal system to the U.S. Standard System, use the same technique.

Subtract the largest whole inch increment from the expression, convert the remainder to eighths of an inch and reduce to the lowest terms (see examples below).

Examples: Subtract the closest whole inch increment from the decimal expression and convert the remainder to eighths (reduce to lowest terms if needed).

a. 4.28' = ?
- 4.25' = 4' - 3"
0.03' = 3/8 = + 3/8"
4' - 3 3/8"

b. 0.89' = ?
- 0.83' = 0' - 10"
0.06' = 6/8 = + 3/4"
0' - 10 3/4"

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c. 8.37' = ?
- 8.33' =
0.04' = 4/8" =

8' - 4"
+ 1/2"
8' - 4 1/2"

d. 0.79' = ?
- 0.75' =
0.04' = 4/8" =

9"
+ 1/2"
9" - 1/2"

Exercise 7: Convert the following to feet, inches, and fractions:

1. 1.59 =

2. 6.87 =

3. 9.36 =

4. .95 =

5. .22 =

6. 3.45 =

7. 1.63 =

8. 10.73 =

9. 1.14 =

10. 12.06 =

11. 11.91 =

12. 4.41 =

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Metric System

The metric system is a base ten system similar to the decimal system. The metric system uses the meter rather than the foot as a basic unit of length measure.

Each meter consists of 10 decimeters and each decimeter consists of 10 centimeters. This same relationship of one unit consisting of ten other units is true throughout the metric system, in fact, we could continue with the breakdown to the billionth if needed. Table 3-3 illustrates the prefix name for each unit of 10 in the metric system.

Conversions between the metric and U.S. Standard system are possible using a variety of different methods. One of the easiest is using what is called a multiplier. The multiplier is used exactly as its name suggests; you simply multiply whatever you need to convert by the appropriate factor. For example, if we needed the distance of 23.75 meters converted to feet, we would multiply 23.75 x 3.281 (Table 3-4) and get 77.92 feet.

Table 3-4 shows some of the multipliers used to convert length measurements. Conversions for other standards of measure are possible with the use of a multiplier also. Appendix A in this manual contains a list of multipliers for various other conversion factors.

Table 3-3: Metric Prefixes

Multiplication Factors	Prefix	Symbol
1,000,000,000,000 = 10^{12}	tera	T
1,000,000,000 = 10^{9}	giga	G
1,000,000 = 10^{6}	mega	M
1,000 = 10^{3}	kilo	K
100 = 10^{2}	hecto	h
10 = 10^{1}	deka	da
(1 Meter) 1 = 10	meter	m
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	mm
0.000 000 1 = 10^{-6}	micro	µ
0.000 000 000 1 = 10^{-9}	nano	n
0.000 000 000 000 1 = 10^{-12}	pico	p

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Table 3-4
Metric / U.S. Standard Multipliers

To Convert From	To	Multiply By
Meters	Inches	39.37
Meters	Feet	3.281
Meters	Yards	1.094
Kilometers	Miles	0.6214
Inches	Meters	0.0254
Feet	Meters	0.3048
Yards	Meters	0.9144

STATIONING SYSTEM

The term "stationing" is defined as "an imaginary numbering system used to describe and locate any point on a construction site." In the United States, this numbering system is based on 100 foot increments.

Stationing will describe a specific location on a project by placing a plus sign (+) between the tens and hundreds column of a length. Figure 3-7 describes a location 1,530.65 feet from the beginning of the stationing system (Station 0+00).

Since the stationing system is based on land survey protocols, projects are not always going to begin at a 0+00 station. This will make it necessary to add or subtract station designations to calculate lengths. For example, if a project begins at station 12+25 and ends at station 19+34, the length of the entire project can be calculated by subtracting the beginning and ending station designation.

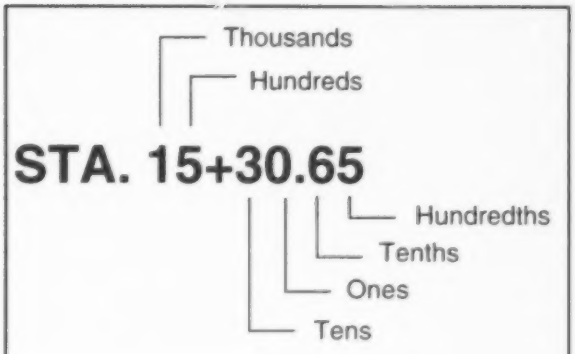

Figure 3-7
Stationing Location

Example: Subtract the beginning station from the ending station:

```
 1934.00   (end station)
-1225.00   (begin station)
 709.00    (length of project)
```

Notice that when you want to calculate a length from station designators, you remove the plus sign and line up the decimal points, as with normal subtraction problems. Remember that when the plus sign is used, it is describing a physical location on a construction site, not a length.

The term "station" can be abbreviated as "Sta." and you may find a wavy line (~) used in place of +00 as shown in Figure 3-8.

Another popular abbreviation for staking and blue prints is to describe a point that is clearly within 100 feet of a station by dropping the major station number and

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using just the "plus" number, as shown in Figure 3-8 at stations 15+50 and 16+50.

Written Instructions

Written instructions such as a project's blueprints must be interpreted the same by all who work with them. For example, if you are instructed to install a fire hydrant at Station 15+30, 30 feet right of centerline, you must interpret the "30 feet right of centerline" instruction to mean the same location as was intended by the project designers.

Directions such as: Up, Down, Right, and Left must follow a certain protocol that is understood by all if error is to be reduced. This protocol makes every written direction based on what is called AHEAD station. In other words, if you are facing the direction the station numbers increase, you are facing ahead station (also called up station) and the project's right side is on your right. If you are facing back station (also called down station), the project's right side is on your left. This is illustrated further in Figure 3-8.

Figure 3-8 also shows a project feature that is located 60 feet away from center line. The proper procedure to locate a point, such as Sta. 16+50, 60 ft. Right is to measure at a right angle (90°) from center line station 16+50.

Up and Down

Similar to the right and left protocol, whether you are on a plus or minus slope is related to ahead station. Figure 3-9 depicts a side view of a project. Ahead station is from left to right; the slope is described as a plus (uphill) slope if it rises in the ahead station direction, and a slope is a minus (downhill) slope if it falls in the ahead station direction.

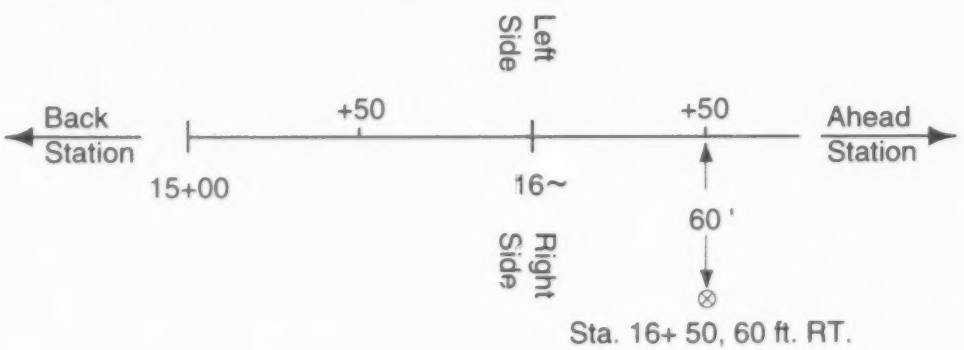

Figure 3-8
Stationing Location

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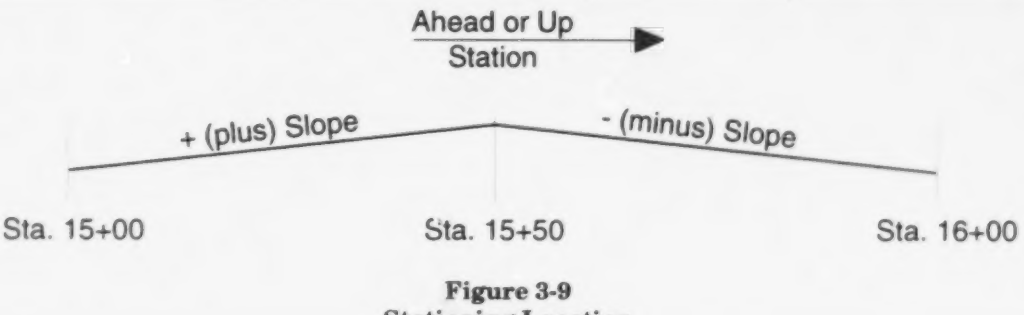

Figure 3-9
Stationing Location

SQUARING PRINCIPLES

Diagonal Length for a Square

Figure 3-10 shows a square 20 foot by 20 foot. The formula shows that to calculate a diagonal, you can multiply a side length by 1.414.

Formula:

Diagonal = side length x 1.414

Example: Square is 20' x 20'

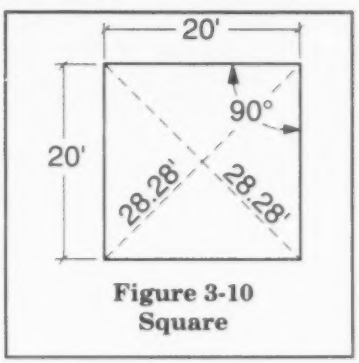

Figure 3-10
Square

diagonal = 20' x 1.414
diagonal = 28.28

Diagonal Length for a Rectangle

Figure 3-11 shows a rectangle 27 foot by 65 foot. The formula shows that you can add the squares of each side together and the square root of that sum will be the length of a diagonal.

Formula: $a^2 + b^2 = c^2$

Diagonal = $\sqrt{c}$

Where: a = width of the rectangle
b = length of the rectangle
c = length of the diagonal
$\sqrt{}$ = square root symbol

Example: Rectangle is 27' x 65'

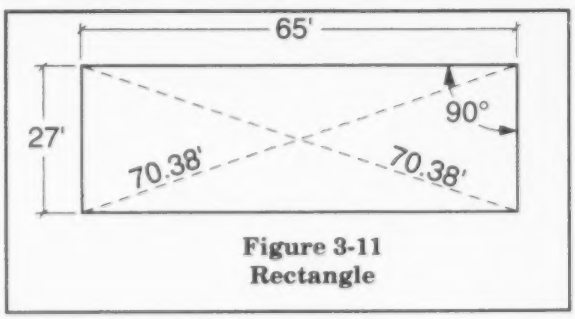

Figure 3-11
Rectangle

diagonal = $\sqrt{(27' \times 27') + (65' \times 65')}$
diagonal = $\sqrt{(729 + 4225)}$
diagonal = $\sqrt{4954}$
diagonal = 70.38'

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Exercise 8: Calculate the length of the diagonals for the following squares. Express your answers in decimal feet.

1. 12'
2. 76.58'
3. 42'- 9"
4. 38.26 meters

Exercise 9: Calculate the length of the diagonals for the following rectangles. Express your answers in decimal feet.

1. 16' x 22'
2. 38.52' x 46.49'
3. 26'-8" x 37'-7 1/2"
4. 12.7 meters x 16.48 meters

SLOPE EXPRESSIONS

In underground utility work you will encounter three forms of slope expression. These are the slope ratio, percentage of slope, and rate per foot.

Slope Ratio

A slope ratio is a horizontal to vertical ratio, where the horizontal portion is always stated first and the vertical portion is always reduced to a unit of one (1). For example, a 2:1 (two to one) ratio describes a slope that is twice as long as it is high. A 1:1 (one to one) ratio describes a slope that is the same height and length. A 1 1/2:1 (one and one-half to one) ratio describes a slope that is one and one-half times as long as it is high.

Slope ratios will commonly be used to describe the angle of slope of a trench or excavation walls. For example, the OSHA regulations state that if no form of trench protection is provided and no soil analysis has been performed, the trench must be sloped to at least a 1 1/2:1 (one and one-half to one) ratio.

Percentage of Slope

Percent means per one hundred. In underground utility work, percentages of slope are used to describe the rise and fall of utilities, such as water and storm drain pipes.

Whenever you express a slope or grade as a percentage, you have indicated a vertical rise or fall over 100 ft. horizontal distance. For example, a 2% slope would rise or fall 2.0 ft. vertically for every 100 ft. horizontally, and a 6.5% slope would rise or fall 6.5 ft. vertically for every 100 ft. horizontally.

To calculate the amount of rise or fall for any length at a percentage of slope, it is easiest to convert the percentage to the third form of slope expression, the rate per foot.

Rate Per Foot

A rate per foot is exactly what the name implies, the amount of vertical rise or fall in a horizontal distance of one foot. In underground utility work, it is commonly used to describe the rise and fall of relatively flat pipes, such as a sewer pipe. A rate per foot expression can be abbreviated, ft/ft, or '/ft., and it may be shown on a set of project blueprints as; S=0.025 (indicating a 2.5% slope).

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The only difference between a percentage of slope and a rate per foot is the placement of the decimal point. The rate per foot of any slope can be calculated by dividing the amount of rise by the length.

Converting from a Percentage to a Rate Per Foot

Converting between the two forms of slope expressions is as easy as moving the decimal point two places. For example, a 2.0% slope is a 0.02 foot per foot and a 3.0% slope is a 0.03 foot per foot slope. To convert from percentages to rate per foot, move the decimal point two places left and add in zeros where needed. To convert from rate per foot to percentages move, the decimal point two places to the right and drop zeros where needed.

Calculating a Rise or Fall using a Percentage Expression

One method to find a vertical distance when the slope is expressed as a percentage is to convert the percentage to a rate per foot (move the decimal point two places left), then multiply by the length in question. The example below demonstrates how to calculate the rise of a pipe that is 18.0 feet in length and is to rise at 3.5%.

Example: Calculate the vertical rise of 18 feet at 3.5%.

Step 1: Convert the percentage to a rate per foot (move the decimal point two places left).

3.5% = .035 ft/ft

Step 2: Multiply the length times the rate per foot.

18 x .035 = 0.63 ft.

For slopes that are already expressed as a rate per foot, simply multiply the length times the rate as done in Step 2 above.

Calculating Percent or Length

The principles of a right triangle will allow you to calculate the length, rate, or rise of any pipe provided you know two of the three pieces of information. For example, if you know how much rise a pipe has in a known distance, you can calculate the rate per foot or percent of slope on that pipe.

Example: In the example below, the pipe is 200' long and has a total rise of 4.0'. Calculate the percent of slope.

Step 1: Divide the length into the rise. (This forms a rate per foot.)

4.0 ÷ 200 = 0.02 (Rate Per Foot)

Step 2: Move the decimal point two places right.

0.02 = 2.0%

To calculate a length, you must know the rate and the amount of rise.

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Example: In the example below, the pipe rises 3.5' at a slope of 1.5%. (You should convert a percentage expression to a rate per foot before dividing.) Calculate the length.

Step 1: Convert a percentage expression to a rate per foot

1.5% = 0.015 ft./ft.

Step 2: Divide the total amount of rise (or fall) by the rate per foot.

3.5 ÷ 0.015 = 233.33 ft. (rounded)

Exercise 10: Calculate the amount of rise or fall for the pipes listed below.

1. Length = 195' Percent = 1.25%
   Rise =

2. Length = 307' Percent = 0.80%
   Rise =

3. Length = 250' Percent = 0.45%
   Rise =

Exercise 11: Calculate the rate per foot and percentage of slope.

1. Length = 400' Rise = 3.0'
   Rate = % =

2. Length = 295' Rise = 5.2'
   Rate = % =

3. Length = 350' Rise = 3.4'
   Rate = % =

Exercise 12: Calculate the length of the following pipes.

1. Rise = 3.0' % = 2.1%
   Length =

2. Rise = 5.2' % = 0.60%
   Length =

3. Rise = 3.4' % = 1.72%
   Length =

Calculating Elevations using Percentages and Rates

To calculate elevations using slope expressions, such as percentages and rates, you must add or subtract the amount of elevation change from or to a starting elevation. For example, if the flow line of a sanitary sewer pipe was at an above sea level (ASL) elevation of 100 ft. and the pipe was designed to rise at a 1.0% for 200 ft. The elevation at 200 ft. away would be calculated by multiplying the rate of 0.01 times the length of 200 ft., and adding that elevation change to the starting elevation of 100 ft. as shown in Figure 3-12.

To calculate the elevation of a point 200 ft. away, multiply the rate times the length and add the elevation change to the starting elevation as shown below:

Step 1: 200 x 0.01 = 2.0 ft. elevation change

Step 2: 100 + 2.0 = 102 ft. ASL

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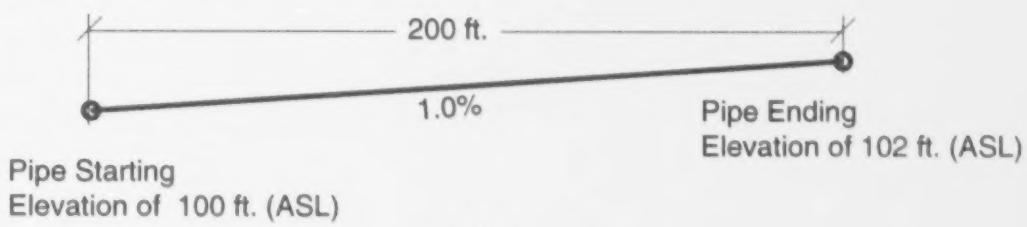

Figure 3-12
Gradient Calculations

Calculating Hub and Flow Line Elevations for a Cut Sheet

A cut sheet is a page of notes that describes the station locations of each stake in an offset referencing line. The cut sheet will describe the elevation of the stake and flow line at each station and record the distance as a "cut" dimension. Figure 3-13 depicts a lengthwise cross-sectional view of a sanitary sewer line with flow line and hub elevations, and the stakes labeled for cut distance and station locations.

A cut sheet for the illustration in Figure 3-13 would look like the sample cut sheet in Table 3-5.

In the sample cut sheet (Table 3-5), the elevation of the hub has already been determined by subtracting the rod shot to each stake from a level at a known elevation (HI).

With the stake elevation already known, the next step is to calculate the design elevation of flow line of pipe at each station. We can accomplish this by multiplying the rate of slope (0.01'/') times the length between stations (25'). This calculation forms a .25' rise between every station.

If we add .25' to the starting elevation, we get the design flow line elevation at station 10+25 of 100.25'. We can repeat the addition of .25' as long as the stations stay 25' apart and the rate of slope does not change.

To calculate the amount of cut, you can subtract the flow line elevation from the stake elevation.

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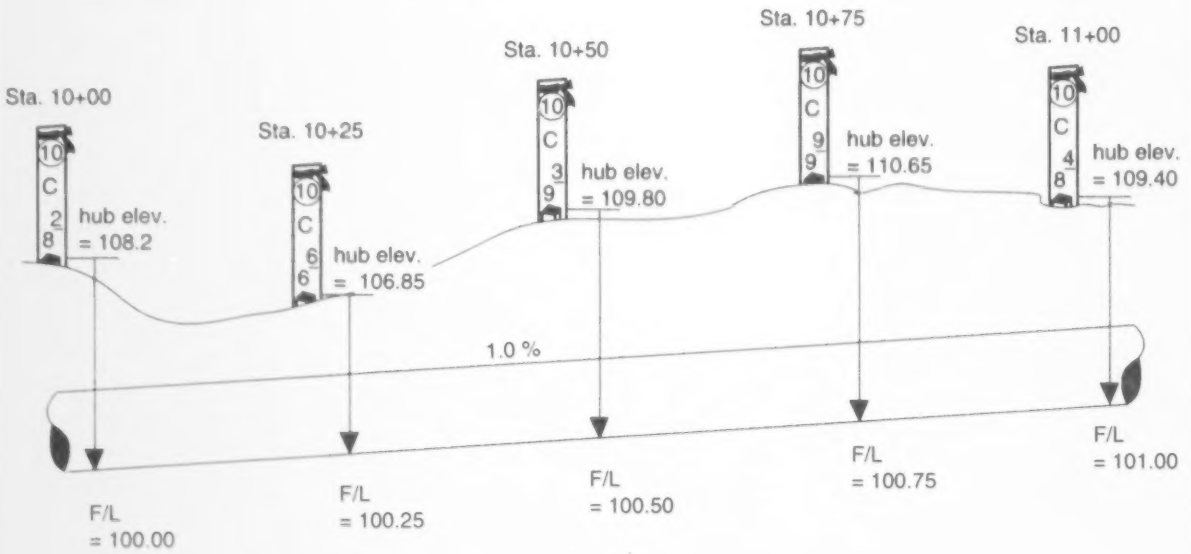

Figure 3-13
Hub & Flow Line Elevation

Table 3-5: Sample Cut Sheet

Bench Elev. _____

Rod Shot @ BM _____

H. I. _____

Station	Rod Shot	Stake Elevation	Flow Line Elevation	Cut/Fill
10 + 00	4.65	108.20	100.00	8.20
10 + 25	6.00	106.85	100.25	6.60
10 + 50	3.05	109.80	100.50	9.30
10 + 75	2.20	110.65	100.75	9.90
11 + 00	3.45	109.40	101.00	8.40

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CUT SHEETS

Cut sheets have important information that can be used by the foreman. The stationing system on the cut sheet helps the foreman direct the crew to a particular work area. Cut sheets also record hub elevations and flow line elevations at each station. The depth of cut on the cut sheet helps determine the type of protection system needed to safeguard the crew. The cut sheet can also indicate the amount of fill to be added for installation of pipe. The following instructions tell you how to fill in a cut sheet accurately:

Cut Sheet Steps (Refer to Table 3-6.)

1. Record bench mark at "Bench Elev."
2. Level transit.
3. Take pole reading on known mark and record in "Rod Shot @ BM."
4. Add pole reading to bench mark elevation which equals HI and record in "HI."
5. Take pole readings on stakes at each station and record station number under "Station" and corresponding pole readings under "Rod Shot" on cut sheet.
6. Subtract rod shots from HI and record under "Stake Elevation."
7. Take pole reading from flow line or beginning invert grade point, subtract from HI, and record under "Flow Line Elevation."
8. Multiply percent of slope times distance from station to station. Add to previous flow line elevation. Record reading for corresponding station under "Flow Line Elevation."
9. Subtract "Flow Line Elevation" from "Stake Elevation" to get "Cut/ Fill."
10. If stake elevation numbers are larger than flow line elevation (pipe invert), the balance equals a cut.
11. If flow line elevation numbers (pipe invert) are larger than stake elevations, the balance equals a fill.

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Table 3-6: Sample Cut Sheet

Bench Elev. _____

Rod Shot @ BM _____

H. I. _____

Station	Rod Shot	Stake Elevation	Flow Line Elevation	Cut/Fill

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ELEVATION CONTROL

A bench mark (abbreviated BM) is a point of known elevation. BMs are usually set and numbered by the United States Geological Survey (USGS) or other official land survey organizations. Since these major bench marks are not always located close to a project, temporary bench marks (TBMs) will be set from official bench marks closer to the project.

The process used to set TBMs and to set control elevations for any construction feature is called a Level Loop or Level Circuit. A level loop begins from a point of previously known elevation (such as a bench mark), performs the elevation control required, and then "checks in" or "closes" with the original or another point of previously known elevation.

In order to perform a legal level loop, the instrument must be picked up and relocated at least once before closing. This process will usually detect if the instrument is damaged or set incorrectly. Since the relocation of the instrument is normally done "around" the location of the rod person, this process is called a "Turn Point."

Turn points consist of two measurements to the same location. One before the instrument is moved and the second after it is moved. The procedure establishes a temporary point of known elevation that is used to calculate the new instrument height after the move.

All elevation control notes should be recorded in a level notebook or other similar record-keeping book. It is crucial to take accurate measurements and record them accurately. These may be checked years later if problems arise or accurate construction elevations are needed. In addition to elevation control information, the notes should consist of factors influencing the project. Notes, such as time of day, weather, work conditions, progress, depth of cut, the type of material, and location may be extremely important after the project is completed.

This documentation will stand up in court *only* if closure of the level circuit was performed correctly. Any changes made to the notebook should be made with a colored pen or pencil and not by erasing notes or calculations.

Level Notebook

A level notebook has six columns that record specific information about the circuit (Figure 3-14).

The first column is usually labeled **STATION** or **POINT** and is used to record the project location of the measurement.

The second column can be labeled either **BS** (back sight) or + (plus), and is used to record rod measurements that establish the instrument height.

The third column records the height of instrument or **HI**. The HI is the actual or assigned elevation of the level crosshair.

The fourth column is called either the **FS** (foresight) or - (minus) column. It contains measurements that are made down from the HI to project features being surveyed and turn points.

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The fifth column contains the actual or assigned elevations measured on the job.

The last column is for comments, such as the bench mark number or other information specific to each measurement.

As shown in Figure 3-14, the number (or name) of the bench mark and/or elevation are recorded in the comments column, the 8.47 measurement is recorded in the BS or + column, and the HI (131.10') is recorded in the HI column.

To Perform a Level Circuit

Figure 3-15 graphically depicts the steps for a simple level circuit and reflects the entries in the example notebook above it.

In order to begin a level loop, you must first establish the **h**eight of **i**nstrument or "HI." To establish the HI, use the grade rod to measure the elevation difference between the level and the bench mark, and add it to the bench mark elevation.

For example in Figure 3-15, the first measurement shows the instrument is set 8.47' higher than the bench mark. The bench mark elevation is 122.67,;therefore, the HI equals the sum of 8.47+122.67 or 131.10'.

Once you establish the HI, all measurements and calulations will be made from that elevation until the instrument is moved.

For example, the elevations for stations 1+00, 2+00, and 3+00 were calculated by subtracting the FS measurement at each station from the HI.

In most level loops, sloping ground or long distances will require you to move the level ahead of the rod person. Anytime you move the level, you must record it as a "turn point" (TP). A turn point establishes a point of known elevation and uses it as a reference elevation to establish a new HI.

STATION	BS (+)	HI	FS (-)	ELEVATION	COMMENTS
	8.47	131.10		122.67	BM #1
Sta 1 ~			10.23	120.87	
Sta 2 ~			12.68	118.42	
Sta 3 ~			17.51	113.59	
TP			13.75	117.35	
	9.15	126.50			
Closure			5.60	120.90	BM #2 ASL=120.92
					Diff. = 0.02

Figure 3-14
Sample Level Notebook

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In this example, the survey crew measured the elevation difference to the turn point, recorded it as a FS measurement of 13.75', and calculated the elevation of that point (117.35). Then they moved the level to a location where they could see back to the rod at the turn point and ahead to BM #2. They reset the level and took a BS reading of 9.15' and added it to the turn point elevation (117.35+9.15=126.50') to establish the new HI.

The notebook will show the turn point with a FS measurement subtracted from the first HI to establish the turn point elevation. The BS measurement is then added to the *turn point elevation* to establish the new HI. The new HI is recorded in its column and used for all measurements and calculations following the turn.

While conducting a turn point, the rod person must know to locate the rod on a distinctive, solid object and to not move or shift it while the instrument is in transit.

In Figure 3-15, the survey party closed the level circuit with BM #2.

The "closing" process is a check on the accuracy of the instrument, as well as a check of your calculations and measurements. It compares the elevation determined in this circuit with the previously known elevation of the bench mark.

In this example, the survey crew started from BM#1 and checked into BM#2 with a difference of 0.02'.

The accuracy required for any level circuit is determined by the type of work being performed. For example, greater accuracy is required to conduct a level circuit that establishes TBMs for future use, than a level circuit that records a cross section of existing ground elevations.

In normal construction surveying, accuracy of ±0.10 feet per mile of circuit is considered adequate.

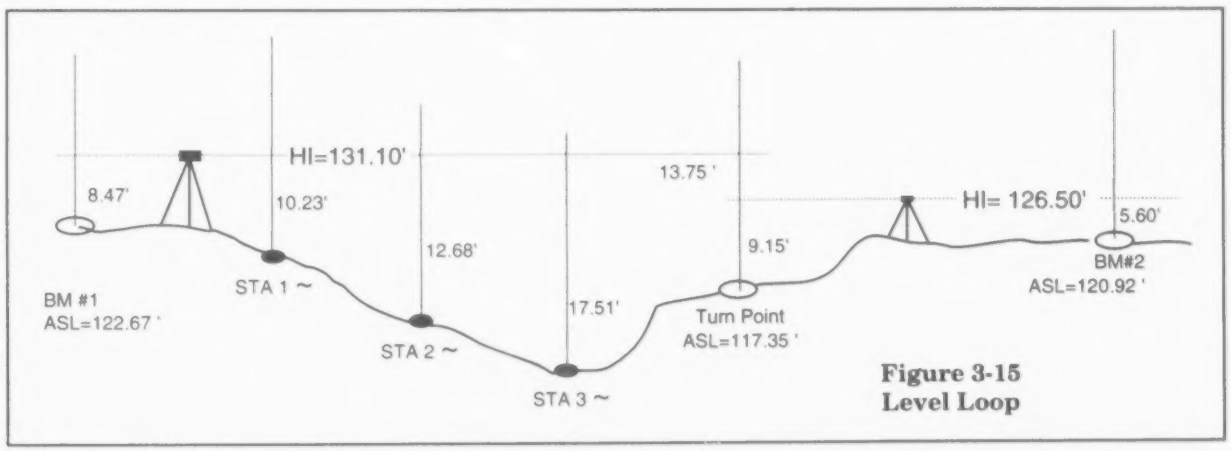

Figure 3-15
Level Loop

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NOTES:

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SECTION III ASSIGNMENT SHEETS

Define the terms:

Level _____

Offset _____

Percentage of Grade _____

Plumb _____

Rate Per Foot _____

Reference Point _____

Square _____

Station _____

Story Pole _____

Slope Ratio _____

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Convert the following expressions from U.S. Standard expressions to decimal feet:

1. 1/4"
2. 5 7/8"
3. 4 7/8"
4. 8 5/8"
5. 16 1/2"
6. 12 3/4"
7. 28 3/4"
8. 10 1/2"
9. 14 3/8"

Give the new station after taking the following measurements from 0+00.00 station.

10. What is the station designation of a point 112.00 feet ahead of 0+ 00?
11. What is the station designation of a point 2341.78 feet ahead of 0+ 00?
12. What is the station designation of a point 47.21 feet ahead of 0+ 00?

Give the new station after taking the following measurements from 16 + 32.29 station.

13. What is the station designation of a point 112.00 feet behind 16 + 32.29?
14. What is the station designation of a point 2341.78 feet behind 16 + 32.29?
15. What is the station designation of a point 47.21 feet ahead 16 + 32.29?

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Calculate the distance between the following stations:

16. Sta. 12+50 to Sta. 15+50

17. Sta. 13+56 to Sta. 18+49

18. Sta. 10+29.95 to Sta. 11+13.69

19. Sta. 133+45.29 to Sta. 138+17.21

20. Sta. 0+51.28 to Sta. 5+36.16

Calculate the elevation differences between the following measurements or elevations:

21. Point #1 measurement = 12.26 Point #2 measurement = 4.32

22. Point #1 elevation = 138.63 Point #2 elevation = 143.16

Calculate the following elevation changes:

23. 3.0% for 150'

24. 1.5% for 187'

25. 0.005'/ft. for 133'

26. 0.0075 '/ft. for 187.32'

27 - 1.84% from Sta. 10+50 to Sta. 11+86

Match the following reference symbols to corresponding definition.

28.

(15)	_____	reference elevation
C 64	_____	horizontal distance
hub = 127.34	_____	1200' feet from 0+00
sta. 12~	_____	vertical distance

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Calculate the elevation of the indicated station by adding or subtracting the elevation change from the starting elevation. Be careful with ahead and back station questions.

	Station	Elevation	Slope	Station	Elevation
29.	Sta. 11+27	675.04	+1.27%	Sta. 13 +15 =	_____
30.	Sta. 25+31.18	130.92	-2.43%	Sta. 27+32.16 =	_____
31.	Sta. 42+39.42	43.96	-1.14%	Sta. 39+39.56 =	_____
32.	Sta. 15+86.23	1215.79	+0.0031'/ft.	Sta. 12+18.89 =	_____
33.	Sta. 437+21.15	764.71	-0.055'/ft.	Sta. 442+19.23 =	_____

The following assignment sheets are designed for a field exercise. Your instructor will give you further instruction and proper procedures. Information in the manual will help you complete this exercise.

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LEVEL NOTEBOOK

Station	BS (+)	HI	FS (-)	Elevation	Comments

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LEVEL NOTEBOOK

Station	BS (+)	HI	FS (-)	Elevation	Comments

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CUT SHEET

Bench Elev. _____

Rod Shot @ BM _____

H. I. _____

Station	Rod Shot	Stake Elevation	Flow Line Elevation	Cut/Fill

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CUT SHEET

Bench Elev. _____

Rod Shot @ BM _____

H. I. _____

Station	Rod Shot	Stake Elevation	Flow Line Elevation	Cut/Fill

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SECTION IV: GRAVITY FLOW PIPING SYSTEMS

Page 110 Terms and Definitions

Page 112 Sanitary Sewer Systems

Page 115 Installation Techniques

Page 125 Low Pressure Testing of Sewers

Page 130 Storm Drain Systems

Page 133 Subdrains and Subsoil Drains

Page 137 Section IV Assignment Sheets

Trainee Objectives

To define the terms:

- Building Sewer
- Gravity Flow
- Main
- Sanitary Sewer
- Sanitary Sewer System
- Sewage
- Sewers or Sewage Systems

To become competent at sanitary sewer installation techniques.

To become competent at storm sewer installation techniques.

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TERMS AND DEFINITIONS

Building Sewer:	Pipe that extends from the main to the inner face of the building wall, commonly referred to as a lateral.
Catch basin:	Receptacle that separates dirt, gravel, and other solids from storm water to prevent them from entering the storm drain system.
Envelope:	Formed with graded permeable granular material, generally a washed screened gravel ranging from 3/4" to 1-1/2". Placed around a perforated pipe, this material forms an area where groundwater can seep in or out.
Filter Fabric:	A woven fiberglass fabic that will allow water to pass, but restricts silt or larger particles. Usually used to surround the envelope and prevent silt and clay from clogging pipe perforations. Can also be used for soil stabilization.
Gravity Flow:	Condition that exists when sewage is conveyed through piping that has been installed on a slope and uses the downward force of gravity instead of pressure.
Inlet:	Used to collect rainwater from paved streets. May be shaped like curb or in the case of a field inlet, shaped like a valley.
Main:	The principle artery of any piping system to which branches will be connected.
Sanitary Sewer:	Piping system designed or used only for conveying liquid or waterborne waste from plumbing fixtures.
Sanitary Sewer System:	Sewage system that carries sewage and industrial wastes, exclusively.
Sewage:	Water-carried waste products or discharge from human beings, or other wastes from residences, public, or private buildings.
Sewers or Sewage Systems:	All structures, conduits, or pipelines by which sewage or industrial waste is collected, transported, and discharged to the point of disposal. This does not include plumbing inside of a building.

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Storm drain: Drain used for conveying rainwater, surface water, condensate, cooling water, or similar discharges.

Storm drainage system: System that is used for conveying rainwater, surface water, condensate, cooling water, and similar discharges to the storm sewer.

Storm sewer system: Sewer system that carries only storm water, surface drainage, or other clean water, and does not carry any sewage or industrial wastes.

Storm water: Rainwater, melted snow, or ice and water in the subsoil.

Storm water drain: Pipe or drain that receives the discharge or rainwater from a building or premises. It may include the discharge of seepage or groundwater which it conveys to the storm sewer.

Subdrain: Drain that is at a level lower than the building drain and the building sewer.

Subsoil drain: Drain that receives only subsurface or seepage water and conveys it to a place of disposal. Part of a drainage system that conveys groundwater from the foot of walls, under basement floors, or from the sub-base of highways to a place of disposal.

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SANITARY SEWER SYSTEMS

The normal sanitary sewer collection system is composed of two parts. The first is the laterals which carry the waste products from the property to the main line, and second is the main lines that run from manhole to manhole toward the treatment facility. After reaching the treatment facility, the waste products are treated before being released into the environment. Most pipes carrying waste products are designed to move the material by gravity flow. Gravity flow means the pipe is laid at enough of a slope to allow the force of gravity to move the material. The waste material is transferred through a series of different sized pipes, usually 4" to 6" at the residence or business (laterals), and 8" and larger for major collector pipes (main lines). Figure 4-1 depicts a plan view of a proposed sanitary sewer collection system in a new cul-de-sac.

Accuracy Requirements

Since sanitary sewers are designed to utilize the force of gravity to keep the waste material moving, the alignment and gradient of these pipes is crucial for the system to work properly. Accuracy is essential during installation and proper construction processes must be followed to ensure that the pipe remains in the originally laid position during backfilling and throughout its design life span. The allowable tolerances during installation vary with the pipe size, but common requirements for 8" pipe range from ± 0.02' to ± 0.03' per joint of pipe. Figure 4-2 shows a gravity flow pipe with the bell ends correctly installed upstream.

Gradients

The amount of gradient needed to allow waste material to flow smoothly depends on factors, such as pipe size and type.

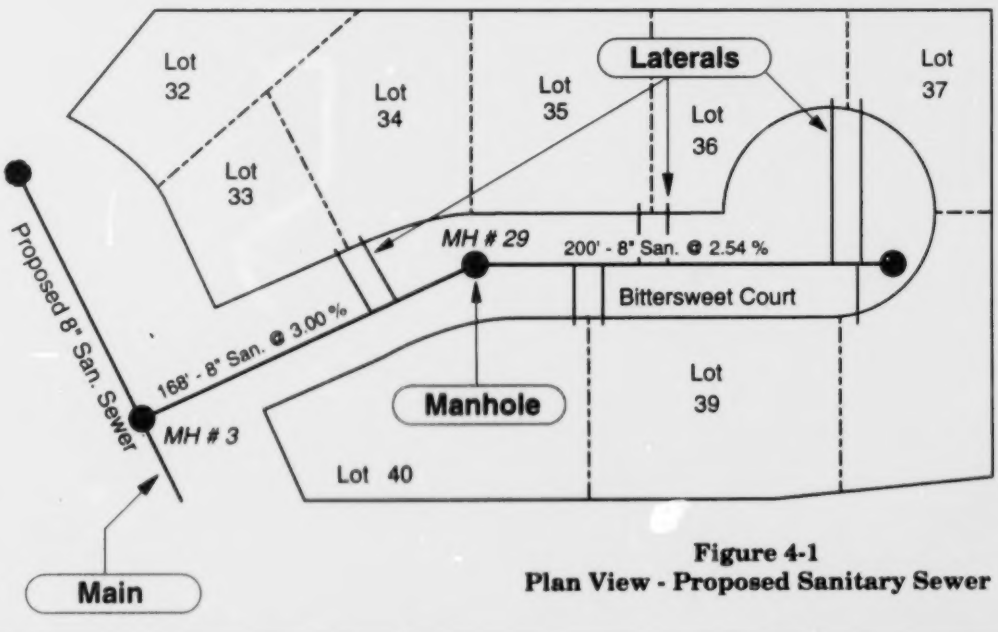

Figure 4-1
Plan View - Proposed Sanitary Sewer

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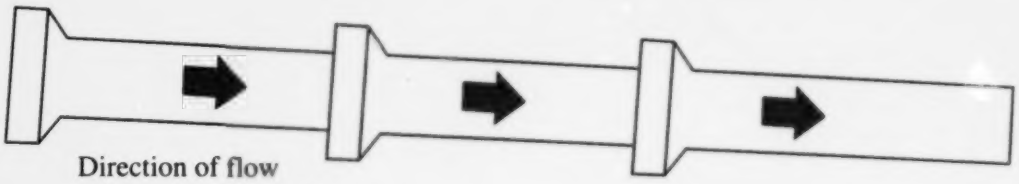

Figure 4-2
Gravity Flow

Table 4-1 is an example of minimum gradients for several pipe diameters. Gradients smaller than this, may not permit the required amount of flow unless other precautions are taken. Installing a sewer line at too steep a gradient can cause blockage as well. When installed too steep, the waste liquids can "run away" and leave the solids behind to cause blockages. Once again, individual projects will vary and differences can be expected. The gradients shown in Table 4-1 are for example purposes only and individual project designs may vary.

Table 4-1:
Minimum Gradients to Permit a Flow of 2 Cubic Foot Per Second

Pipe Diameter	Minimum %
6"	0.62
8"	0.40
10"	0.28
12"	0.22
15"	0.16
18"	0.12
21"	0.10
24"	0.08
30"	0.07
36"	0.06
42"	0.045
48"	0.04

Pipe Types

Pipe types commonly used for sanitary sewer construction include vitrified clay, PVC, reinforced concrete, and ductile iron.

Vitrified clay pipe (Figure 4-3) is one of the first pipe types used in sanitary sewers. Clay pipe is resistant to chemicals found in both sewage and the soil. It is a rigid pipe that breaks easy; it must be handled and installed carefully to prevent damage.

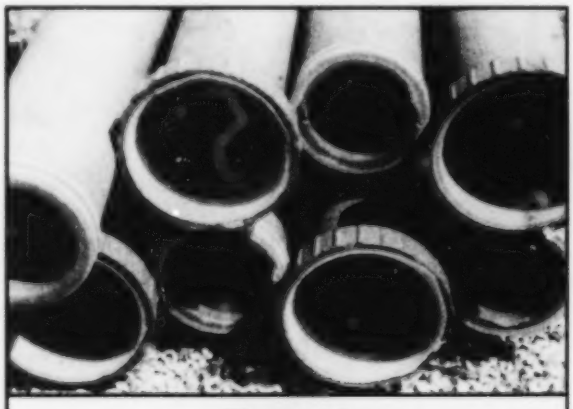

Figure 4-3
Vitrified Pipe with
Bell End/ Spigot End

Two types of joints are available on vitrified clay pipe, bell ends formed of clay and plastic bell ends which are fused onto the pipe. Both joints use an o-ring-type rubber gasket to form the seal.

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Pipe joints range in length from 2' to 6'. Tees or wyes for laterals are specially manufactured pipe sections.

Polyvinyl Chloride (PVC) (Figure 4-4) pipe has become widely used in sanitary sewers because of its strength, light weight, chemical resistance, low friction properties, and ease of handling. PVC pipe is manufactured in sizes from 4" to 24" and in 20', 13', and 12-1/2' lengths.

Figure 4-4
PVC Pipe with Slip Joints

This pipe is not rigid and must be properly bedded to maintain alignment.

PVC pipe joints and fittings are joined using rubber gasket push-on type joints or solvent cement joints.

Wyes and tees for PVC pipe can be fittings or saddles. To install a service saddle, a hole must be cut into the main and the saddle banded to the pipe. These fittings or saddles can use a rubber gasket or solvent cement seal. Figure 4-5 shows pre-manufactured service fittings with gasket type seals.

Reinforced concrete pipe (RCP) is generally used in sanitary sewers larger

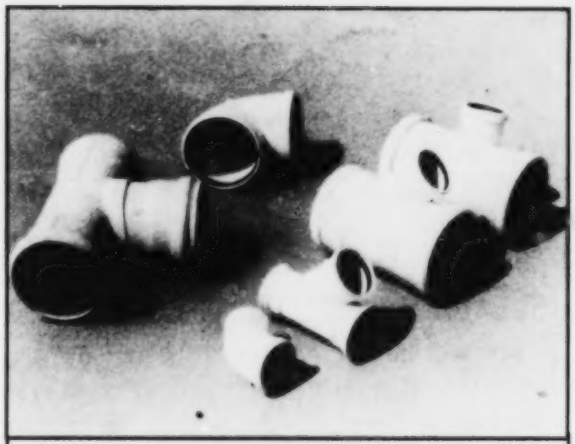

Figure 4-5
Manufactured PVC Fittings

than 24" because other pipe types are not available in these large sizes. RCP is concrete pipe with wire reinforcing. Because of its greater strength, it can be buried deeper than other pipe types. RCP is manufactured in lengths from 4' to 8' and 12" to 108" in diameter. Pipe sections are commonly joined using an o-ring-type rubber gasket as shown in Figure 4-6.

Figure 4-6
Reinforced Concrete Pipe (Slip Joints)

Openings for service laterals in RCP are made with a hammer and chisel or a core drill. Tees or wyes are attached with

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mortar. Concrete pipes may have to be coated or lined depending on the soil and the type of waste material.

Ductile iron pipe (D.I.) is also used for sanitary sewer. Because of its strength, ductile iron pipe can be buried deeper than other types of pipe. Ductile iron pipe joints are available in 18' or 20' lengths. The length and rigidity of D.I. pipe helps maintain line and grade.

D.I. pipe can be joined using rubber gasket push-on joints or mechanical joints, as discussed in pressure water system installation (Figure 4-7).

D.I. pipe is coated with a concrete lining on the inside to resist chemicals from sewage, and depending on soil conditions, may have to be wrapped with polyethylene to prevent corrosion. Fittings for service laterals can be installed in the main using mechanical joints or by cutting a hole in the pipe with a portable all-purpose saw and using a bolt-on service saddle.

Figure 4-7
Ductile Iron Pipe
(Slip & Mechanical Joints)

INSTALLATION TECHNIQUES

Installation techniques for gravity flow systems include:

- Trench Excavation
- Bedding Materials
- Pipe Installation
- Haunching of Pipe
- Initial backfilling

Figure 4-8 depicts some of the terminology used with pipe installation.

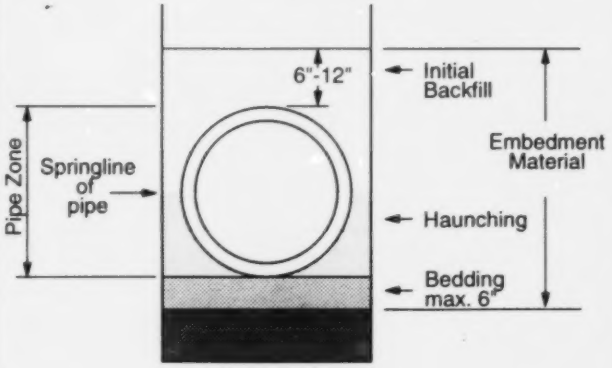

Figure 4-8
Initial Embedment

Trench Excavation

Trench excavation is controlled by the use of grade stakes offset from center line of pipe. These stakes indicate the distance horizontally to center line of pipe and vertically to flowline of pipe. Batter boards and stringlines or lasers are used in conjunction with the grade stakes to establish subgrade and pipe grade in the excavation.

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Bedding Materials

The existing material, where the pipe is to be installed, will determine if a bedding material is required. Table 4-2 shows a sample material designation describing the physical characteristics of different class soils. If the existing material does require a bedding, the design will usually specify 4" to 6" of material under the pipe. The purpose of bedding the pipe is to provide a firm, stable, and uniform support for the pipe.

Table 4-2
Description of Existing Materials

Class	Material Description
Class I	Angular, graded stone, crushed stone and other materials, such as coral slag and cinders from 1/2" to 1-1/2" in size.
Class II	Course sands and gravel to 1-1/2" in size.
Class III	Fine sand, sand-clay, and gravel-clay mixtures.
Class IV	Silt, clay, and silty clay.
Class V	Organic soils, frozen soils, debris, rocks larger that 1-1/2", and other foreign materials.

When the bottom of the excavation contains Class II or III materials, select bedding will not be necessary, as these materials are suitable for pipe installation. If bedding is to be used, it must be compacted to provide satisfactory support for the pipe.

After bedding materials are placed and compacted, prepare the trench bottom for pipe installation by removing large stones and dirt clods, and grading with a shovel. Dig a bell hole so the pipe is uniformly supported along its entire length. Check trench bottom to be sure the material is at the proper grade.

Pipe Installation

Prepare the previous pipe bell for the next pipe. Most sanitary sewer pipes are joined by means of a rubber gasket push-on-type joint. Clean the bell and rubber gasket with a clean dry cloth and apply lubricant to the gasket. Lower the next pipe section into the trench, and clean and lubricate the spigot end. Be careful to keep both ends free of small stones and sand. Debris between the gasket and spigot will cause a leak.

Insert the spigot end into the bell until it comes in contact with the gasket. Push the spigot into the bell until it reaches the reference line by using a bar and wooden block. Set the pipe to line and grade, and place backfill near the bell end to secure it.

Haunching of Pipe

The haunching area is from springline to the bottom of pipe and is the most important factor in maintaining the alignment of a flexible pipe. This area must be compacted to the required density to provide necessary support for

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the pipe to prevent deforming from the weight of backfill material. Compaction of the haunching area must be from the pipe to the undisturbed trench walls. If Class I, II, or III material was used as bedding, the same material can be used for haunching.

A tamping bar, commonly called a "T-bar," may be used to compact material under the pipe and around joints (Figure 4-9). A flat tamper can be used at the sides between the pipe and trench walls. Depending on pipe size, haunching material should be added in 4" lifts to springline of pipe.

Figure 4-9
Haunching to Springline of Pipe

Initial Backfilling

Initial backfill begins at the pipe springline to a level 6" to 12" above the top of the pipe. Class II and III materials are satisfactory for initial backfill. The backfill should be placed in 6" layers and mechanically compacted using a rammer or vibratory plate compactor depending on the material. Care must be taken to avoid contact between the pipe and compaction equipment. Remove any large stones which could damage the pipe.

After initial backfill material is in place, the final backfilling operation can begin to fill excavation to the desired grade.

Purpose of Manholes

Since the waste materials' only source of movement comes from gravity, any change of direction can cause a blockage, unless precautions are taken to smooth the transition from one direction to another. For this reason, a sanitary sewer line will usually change direction only in a manhole.

By placing all direction changes in manholes, maintenance can be performed relatively easily on these trouble areas. Another purpose of a manhole is to provide access for main line cleaning operations. Manholes will usually be placed from 200' up to 400' apart for this reason. Figure 4-10 shows a standard cross-section drawing of a Type A manhole designed to accommodate pipes from 8" to 24" diameter.

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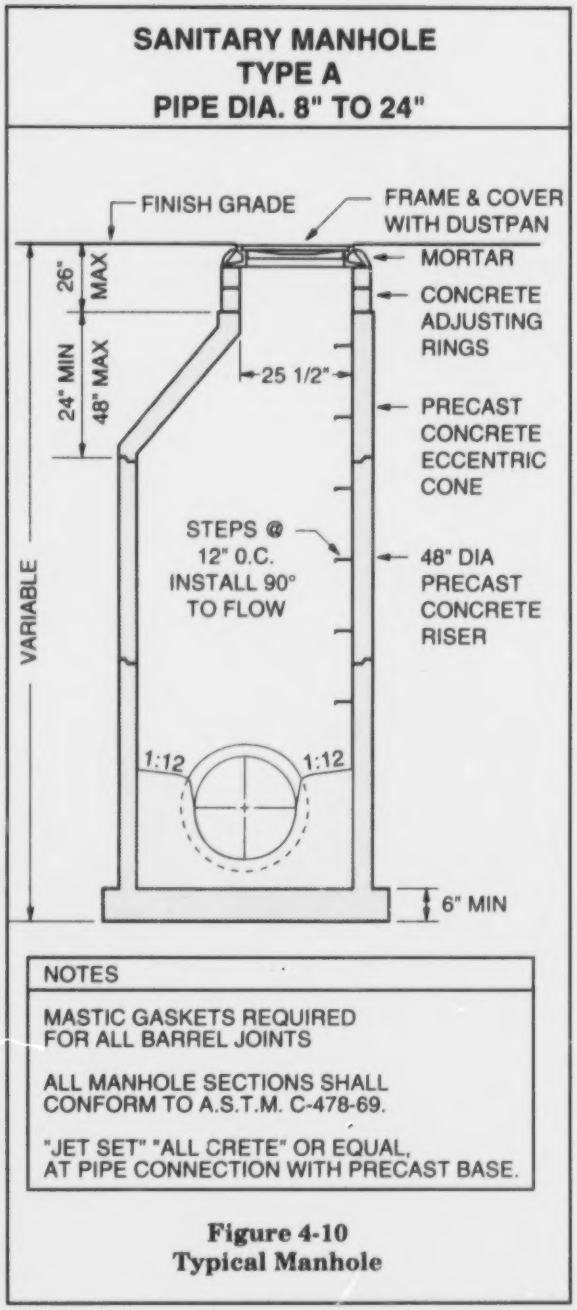

Figure 4-10
Typical Manhole

Drop Inlets

A drop inlet will be designed whenever the elevation of the pipe entering the manhole cannot be dropped close to the same elevation of the main line running through the manhole. At an elevation difference of 2' or greater, the specifications will usually require a drop inlet.

The elevation change is made using an outside drop which enters at the bottom of the manhole. In Figure 4-11, the pipe entering the manhole is constructed with a tee fitting that continues into the side of the manhole at the same grade as the rest of the pipe. The side bore of the tee is pointed downward and constructed with a 90° bend at the bottom of the drop.

As noted on the drawing, the bottom of the drop should be the same elevation as the spring line of the main running through the manhole.

There are other considerations concerning the construction of drop inlets:

- What type of sealers are required where the pipes join the manhole?
- What kind of straps are required to secure the drop pipe to the manhole?
- What type of bedding is needed for different size drop inlets?

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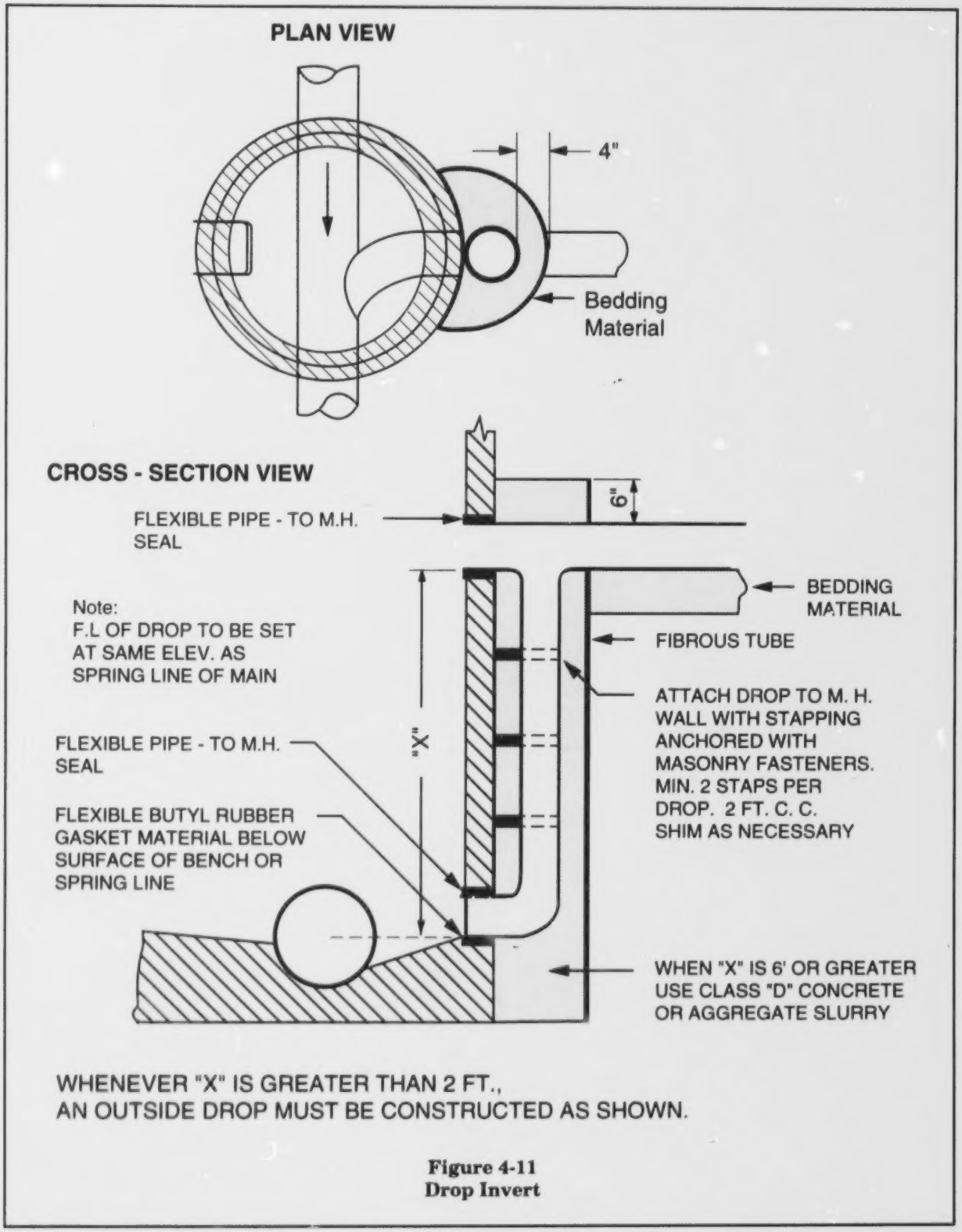

Figure 4-11
Drop Invert

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Sanitary Sewer Cleanouts

Similar to most residential plumbing systems, main line sanitary sewers are usually equipped with a design feature called a "cleanout." A cleanout is usually built at the end of a main line and after all laterals like at the end of a main line in a residential or commericial cul-de-sac.

Cleanouts are constructed at a 45° angle to allow easy insertion of a flush hose or snake and will rise to the street surface where the cleanout is capped. Figure 4-12 shows a standard drawing of a cleanout and lid assembly.

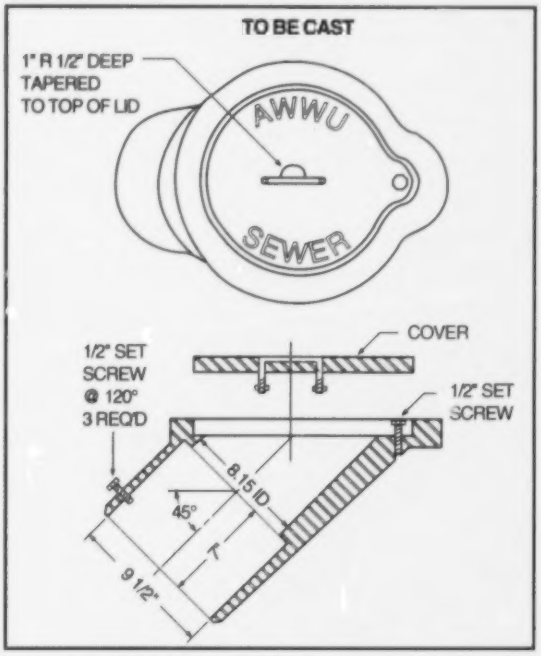
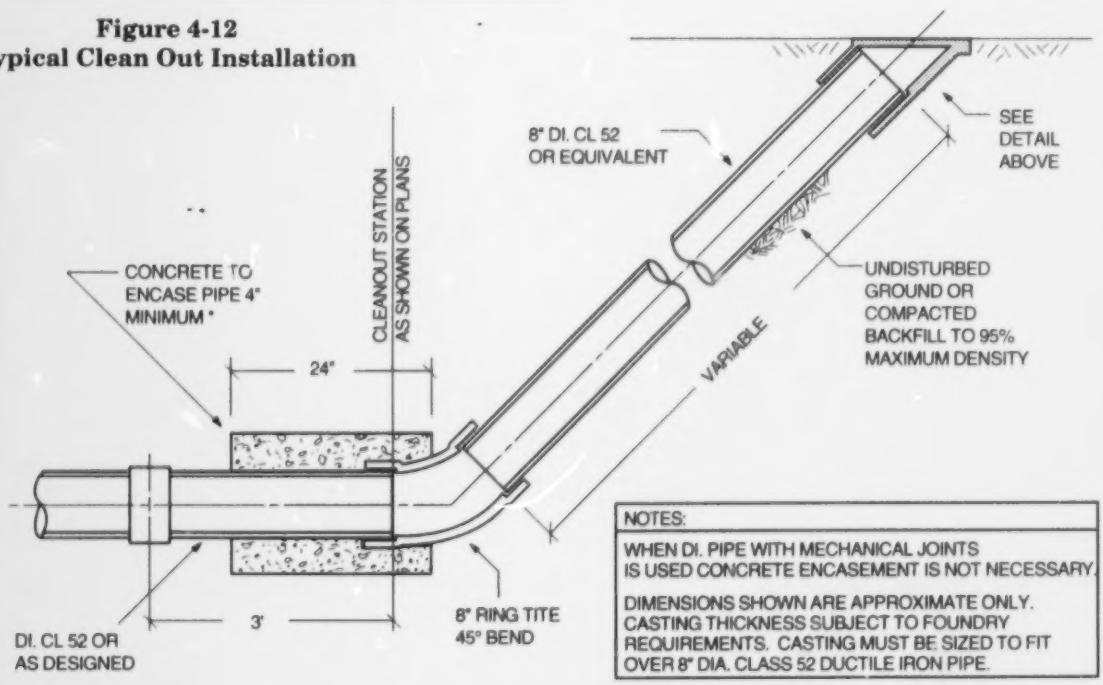


Figure 4-12
Typical Clean Out Installation


8" DI. CL 52 OR EQUIVALENT
SEE DETAIL ABOVE
CONCRETE TO ENCASE PIPE 4" MINIMUM *
CLEANOUT STATION AS SHOWN ON PLANS
24"
VARIABLE
UNDISTURBED GROUND OR COMPACTED BACKFILL TO 95% MAXIMUM DENSITY
3'
DI. CL 52 OR AS DESIGNED
8" RING TITE 45° BEND
NOTES:
WHEN DI. PIPE WITH MECHANICAL JOINTS IS USED CONCRETE ENCASEMENT IS NOT NECESSARY.
DIMENSIONS SHOWN ARE APPROXIMATE ONLY. CASTING THICKNESS SUBJECT TO FOUNDRY REQUIREMENTS. CASTING MUST BE SIZED TO FIT OVER 8" DIA. CLASS 52 DUCTILE IRON PIPE.

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Installation of Laterals (Building Services)

A lateral is a pipeline which transfers waste from a residence or business to the sewer main. This pipe runs perpendicular to the main and is connected using different fittings depending on the depth and type of pipe.

Laterals begin by installing a "service" saddle on the sewer main. For PVC pipe, these connections are made using either solvent weld or gasketed applications.

Sewer Saddle Assembly Procedures (solvent weld)

1. Place saddle on pipe and use as template to mark opening (Figure 4-13). Remove saddle.

Figure 4-13
Cutting Saddle Hole

2. Using a saber saw, cut hole in pipe by holding the blade horizontally and press down until it cuts through the pipe wall. Cut hole about 1/2" larger than the mark to accommodate the saddle stem. Do not allow the cutout piece or any foreign materials to enter the pipe during this operation.

3. With a clean dry cloth, wipe clean the underside of the saddle and the area around the opening on the pipe.

4. Apply primer to both mating surfaces. While the primer is still wet, apply solvent cement to both surfaces.

5. Immediately place the saddle over the opening and draw down with metal straps. The saddle must not be moved once both surfaces make contact.

For gasket fittings the procedure is the same, except the gasket forms the seal instead of primer and solvent cement.

The position of the saddle on the main will be determined by the depth of the main. When the main is more than 12' deep, the saddle is positioned on top of the main and a vertical riser is used to change the elevation of the lateral to allow it to be laid at the desired slope into the building. If a riser is not required, the saddle must be placed on a 45° angle from the top of the pipe. A 45° bend is used to provide the desired direction for the lateral (Figure 4-14).

Figure 4-14
Installed Saddle

Lateral pipe installation techniques are the same as the mainline pipe, except for line and grade. Line is usually sighted from the service saddle connection to the end marker inside the property line.

Grade is maintained by the use of a torpedo level, set at 1/4 bubble on each pipe joint (Figure 4-15). A 2' level with a small block taped on one end can also be used. The size of the block is determined by the amount of slope of the pipe. Specifications usually require a slope of 1/8"/ft min. to 1/2"/ft max.

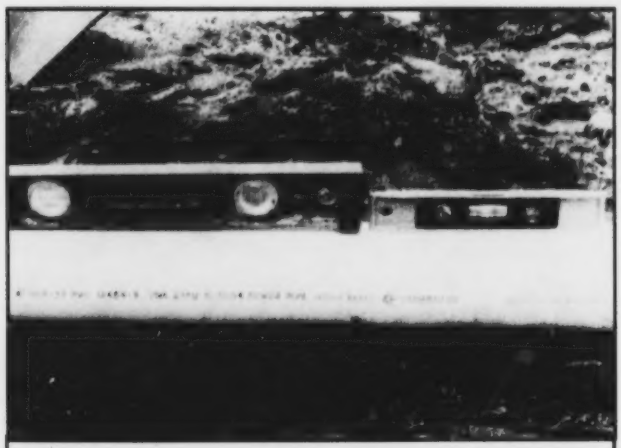

Figure 4-15
Lateral Installation with Level

When lateral installation is complete, the end is capped and marked with a 2 x 4, and backfilled.

Repair and Tie-in Methods

When making repairs to gravity flow pipe, the most common method is the use of flexible couplings. Flexible couplings are available in sizes from 1-1/4" to 15". These couplings come in all shapes and sizes and can be used to connect different pipe types and different pipe sizes with one coupling. These flexible couplings are fastened with stainless steel bands, much like a large hose clamp, to make the seal (Figure 4-16).

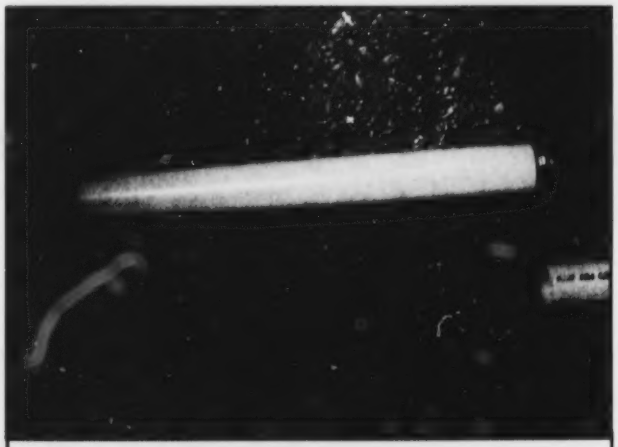

Figure 4-16
Repair Piece with Flexible Coupling

Repair Procedures:

1. Excavate completely around damaged pipe. Be sure excavation is safe from cave-ins before starting work on pipe.

2. Mark pipe section to be removed, and be sure the cut is square to ensure proper assembly.

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Most plastic pipe can be cut with a hand saw. Ductile and concrete pipe must be cut with a portable all-purpose saw.

3. Cut the replacement pipe section about 1/2" shorter than the opening between the two pipe ends. Be sure all pipe ends are free of burrs and dirt which may cause a leak between the pipe and the flexible coupling.

4. Slide the two flexible couplings completely onto the repair section of pipe. Put stop marks on the two pipe ends to be repaired. The marks are needed to center repair coupling over the joint (Figure 4-17).

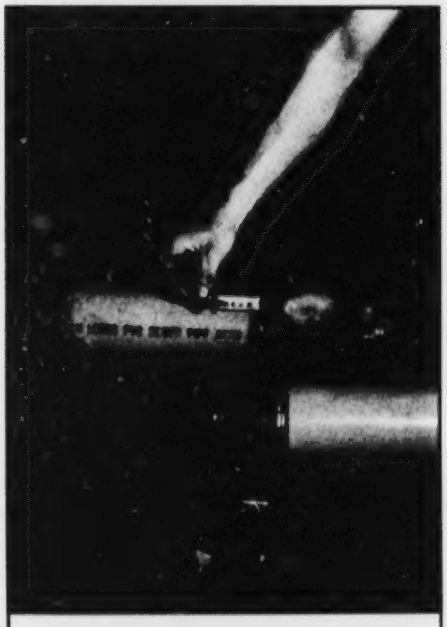

Figure 4-17
Centering Flexible Couplings

5. Lower the replacement assembly into excavation and place between the pipe ends. Slide the repair couplings onto the pipe ends to the stop marks.

6. Tighten steel bands to the required tension. Pressure test the repair before backfilling to be sure of no leaks.

The completed repair should look like Figure 4-18 when finished.

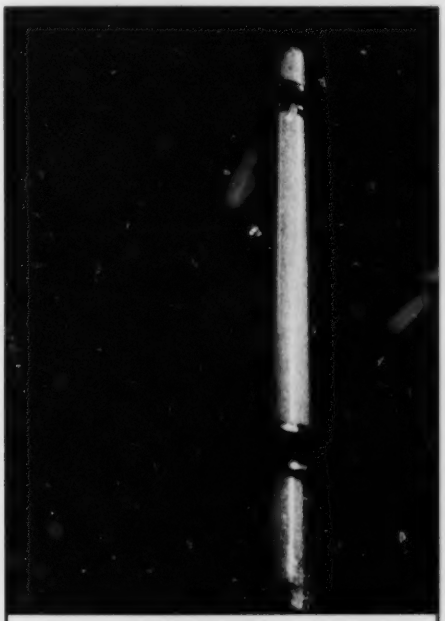

Figure 4-18
Repair Couplings Installed

Some PVC manufacturers have a fitting called a Double Bell Coupling which can be used in place of flexible couplings.

Double Bell couplings use a gasket to make the seal just like a push-on joint. The repair is made the same as with the flexible couplings, except the four pipe ends must be beveled and lubricated to accommodate the push-on type gaskets.

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Repair Procedures, Concrete Pipe Larger than 15" in Diameter

1. Remove entire section of damaged pipe. Be careful not to damage the bell or spigot end of the pipes left in place. (Figure 4-19)

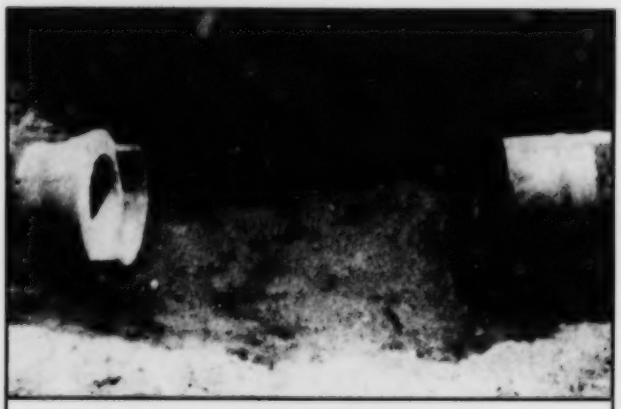

Figure 4-19
Damaged Section Removed

2. Use a portable all-purpose saw to remove the top half of the bell end of the existing pipe and half of the bell end of the replacement pipe as shown in Figure 4-19. (Remove only the lip of the bell that receives the gasketed spigot end.)

3. Prepare spigot ends with gaskets and lubricant as with a normal joint.

4. Lower replacement pipe into excavation with remaining bell section on top (Figure 4-20).

5. Slide the pipe sling around the repair pipe, so lifting the pipe will rotate the remaining bell to the bottom (Figure 4-21). The new spigot end will cradle in the remaining half of the existing bell. The new bell must be held against the existing spigot and backfilled to hold it in place.

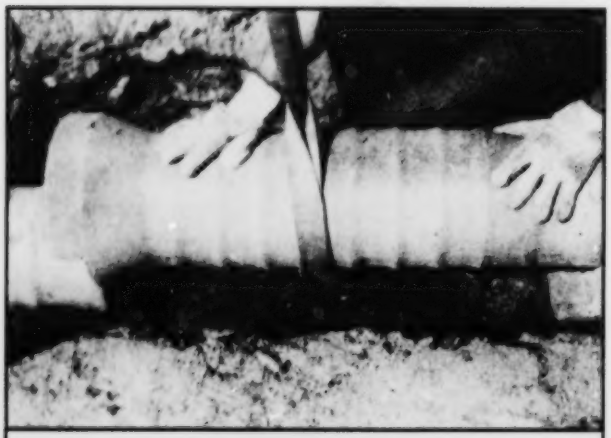

Figure 4-20
Lowering In Repair Section

Figure 4-21
Rotating Bell to Bottom

6. Use mortar to patch where the bells were removed and complete backfilling.

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LOW PRESSURE TESTING OF SEWERS

The low pressure air test is a test which determines the rate at which air under pressure escapes from an isolated section of sewer pipe. The rate of air loss is intended to indicate the presence or absence of pipe damage, and whether or not the joints have been properly constructed. The test is not intended to indicate water leakage limits.

The low pressure air test is used on pipes from 4" to 24" in diameter. Larger pipes may be more conveniently accepted by visual inspection and individual joint testing.

Safety is important when air testing because of the pneumatic forces applied to inflatable test plugs. An 8" plug will have 250 pounds of force on it when the pipe has a pressure of 5 psi. Pressurizing equipment should be equipped with a pressure relief device set at 10 psi. All plugs installed must be braced to prevent blowouts when air pressure is applied. No one should be allowed in the manholes during testing.

Figure 4-22 depicts a schematic illustration of the test apparatus set up and a drawing showing the test plug installations.

Testing Procedure:

1. Flush the line to remove debris from construction. A wet line will provide a better test.
2. Plug the section of pipe to be tested using the inflatable plugs. Be sure all plugs are securely braced. One of the plugs must have a provision for connecting the air supply.
3. Slowly pressurize the pipe to approximately 4 psi and allow the pressure to stabilize for a short time. The low pressure gauge should be in the line between the air source and the pipe.
4. Pressure is allowed to drop to 3.5 psi and the air source valve is closed. The time it takes the pressure to drop from 3.5 psi to 2.5 psi is recorded, and used to compute the rate of air loss and determine if the line is acceptable.
5. After the test is completed, a valve is opened and the remaining air is released.

Do not enter the manhole or remove plugs until all of the air pressure has been released.

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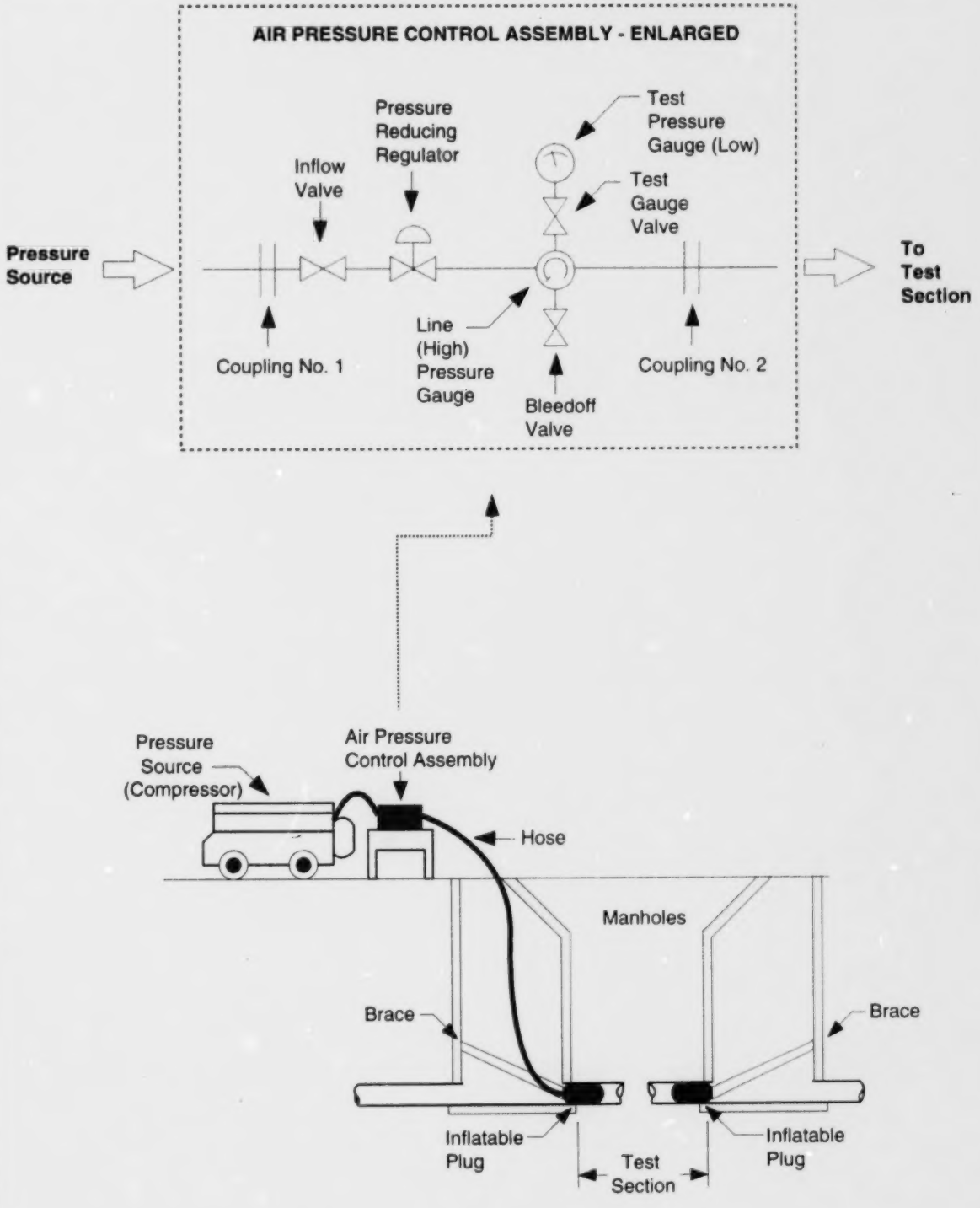

Figure 4-22
Low Pressure Air Test Set up

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Figures 4-23 and 4-24 depict different sizes of inflatable plugs along with plug and pump installation.

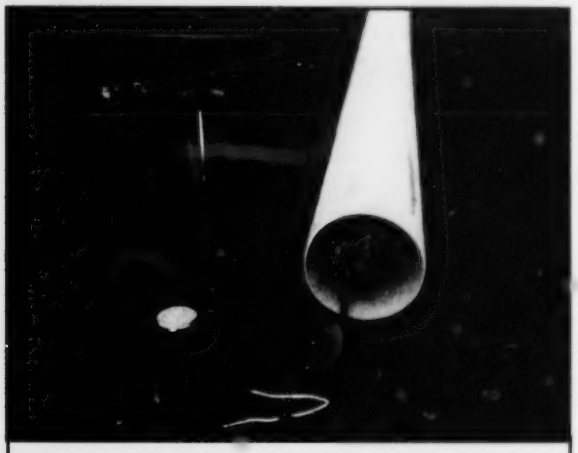

Figure 4-23
Inflatable Test Plug Installation

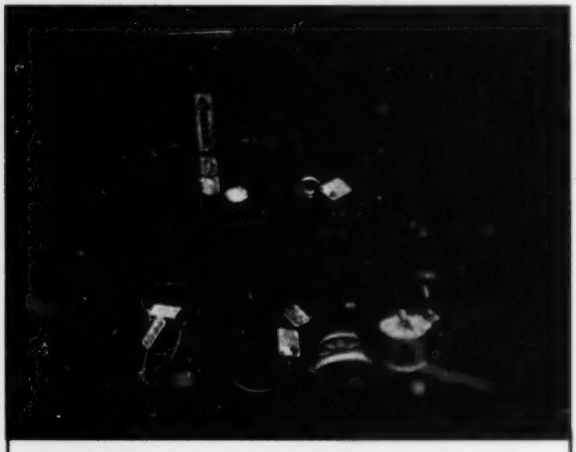

Figure 4-24
Test Plug Types with Hand Pump

Air Pressure Time Loss Calculation

Table 4-3 depicts the minimum amount of time in minutes and seconds for a section of sewer line to drop from 3.5 psi to 2.5 psi. Once you know the length and diameter of pipe, you can use the table to calculate the amount of time you are allowed to drop one pound in pressure.

You need to know three factors whenever you do any time pressure calculations:

- Pipe diameter
- Pipe length
- Test time per foot (Table 4-3)

We will perform calculations for different lengths of 15" pipe. To find the pipe diameter, look in Column A. You use the Column B numbers for any length up to the length given in Column C. We will use 2.5 seconds in our formula for 15" pipe up to 170 feet long.

1. Calculate the maximum time you are allowed to drop 1 psi for 150' of 15" pipe:

   pipe diameter = 15 inches
   pipe length = 150 feet
   test time per ft. = 2.5 seconds

   Time = 2.5 seconds x 150'
   = 375 sec.
   = 6.25 min.

The .25 minutes must be converted to seconds:

= .25 min x 60
= 15 seconds
= 6 minutes: 15 seconds
Time = 6:15

You must maintain less than 1 psi drop for a minimum of 6 minutes, 15 seconds. If your test pressure gauge drops below 2.5 psi before 6 minutes and 15 seconds pass, your pipe has failed the pressure test. As an example, if we lose more than 1 psi in 5 minutes and 45 seconds, our pipe has failed the test. If we lose less than 1 psi in 7 minutes and 10 seconds, our pipe has held up well.

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2. Calculate the maximum time you are allowed to drop 1 psi for 250' of 15" pipe:

   pipe diameter = 15 inches
   pipe length = 250 feet
   test time = 7:05

Since the pipe length falls between 170 feet (Column C) and 382 feet (Column E), our test time has already been calculated (Column D). The test time for any length pipe between 170' and 382' for 15" pipe, will be 7 minutes and 5 seconds.

3. Calculate the maximum time you are allowed to drop 1 psi for 400' of 15" pipe:

   pipe diameter = 15 inches
   pipe length = 400 feet
   test time per ft = 1.11 seconds

   Time = 1.11 seconds x 400'
   = 444 seconds
   = 7.4 minutes

   The .4 minutes must be converted to seconds:

   = .4 min x 60
   = 24 seconds
   = 7 minutes: 24 seconds

   Time = 7:24

Table 4-3: Low Pressure Air Test Time

A Pipe Diameter (Inches)	B Time Per Foot Up To Length In Column C (Seconds)	C Test Length (Feet)	D Test Time For Any Length Between Column C & E (Min:Sec)	E Length At Which Time In Column F Applies (Feet)	F Time Per Foot Per Total Length (Seconds)
4	0.18	636	1:54	1432	0.08
6	0.40	424	2:50	955	0.18
8	0.71	318	3:47	716	0.32
10	1.11	255	4:43	573	0.49
12	1.60	212	5:40	477	0.71
15	2.50	170	7:05	382	1.11
18	3.62	141	8:30	318	1.61
21	4.92	121	9:55	273	2.19
24	6.42	106	11:20	239	2.85
27	8.14	94	12:45	212	3.62
30	10.00	85	14:10	191	4.44
33	12.14	77	15:35	174	5.40
36	14.34	71	17:00	159	6.39

Notes:
Specification time (Min:Sec) required for loss of air pressure from 3.5 psi to 2.5 psi for size and length of pipe indicated. (Based on 0.003 cfm per sq. ft. with a minimum loss of 2.0 cfm and a maximum of 4.5 cfm.)

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Invert Construction and Shaping

Inverts are concrete flowlines inside a manhole, shaped to match the flowline and diameter of the adjoining pipes. Their purpose is to allow access to the main pipe for cleaning, as well as to smooth the transition for sewage entering the main line from other directions. Since any change in direction is a likely location for blockages, it is crucial that the invert be shaped as smooth and even as possible.

Often manholes can be ordered from the manufacturer with the inverts preshaped and installed. Specific project situations; however, will usually require some on site frabrication. Area practice and specifications will determine the depth of the invert and the slope of the benches in the manhole, so be sure to consult your local specifications.

Figure 4-25 shows a cross-section view and different styles of inverts.

Inverts can be shaped in several ways:

1. The pipe can be laid through the manhole using the pipe as a template. After the invert and benches are set up, the top half of the pipe can be removed.

2. Concrete can be placed in the manhole and shaped by hand using a straight edge and hand float. A short section of pipe can also be used to hand shape the invert.

Inverts should be shaped smooth and even to allow sewage to pass freely through the manhole to prevent clogging and unnecessary maintenance.

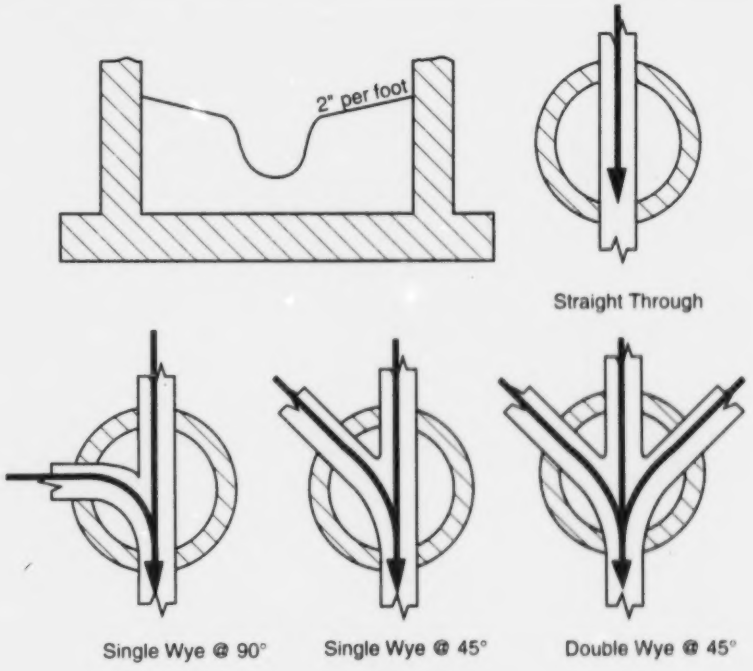

Figure 4-25
Invert Construction

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STORM DRAIN SYSTEMS

General Overview and Principles

Storm drain systems consist of catch basins, inlets, manholes, lead pipes, and main lines. Catch basins and inlets receive storm water from paved streets, parking lots, athletic fields, etc. Lead pipes connect inlets and catch basins to the main line. These connections are usually made at a manhole, but can be hooked directly to the main line pipe. The main line storm drain then conveys the storm water to an outfall which empties into a river or other natural drainage area. Figure 4-26 shows a storm drain manhole connected to leads that collect water from the curb inlets.

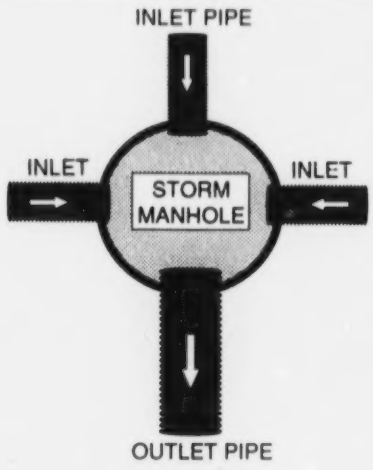

Figure 4-26
Storm Drain Manhole

Accuracy Requirements

Storm drainage systems, like sanitary sewers, convey storm water using gravity flow conditions. Since most storm sewer mains use large pipe, the amount of slope is sometimes slight. Accuracy of installation is important on slight slopes because a small amount of misalignment will leave an area of standing water in the pipe which could cause deterioration and eventual buildup of sediment that could cause clogging. Tolerances on pipe joints will vary (i.e., 0.02'/' on an 8' concrete pipe joint to 0.05'/' on a 20' corrugated metal pipe joint).

Pipe Types

Storm sewers are constructed using three major pipe types: Reinforced Concrete Pipe (RCP), Corrugated Metal Pipe (CMP), and Corrugated Polyethylene Pipe (CPP).

Reinforced Concrete Pipe (RCP) - Is widely used in storm sewer construction because of its strength and durability. Available in numerous sizes and strengths, RCP can satisfy many performance requirements. Joint gaskets and sealants vary in cost and performance characteristics (Figure 4-27).

Performance characteristics, such as resistance to infiltration of groundwater, resistance to exfiltration of storm water, smooth flow lines, and ease of installation depend greatly upon proper installation and backfilling. RCP utilizes two types of rubber gaskets: flat, compression type, and o-ring type. Except for the roll-on gasket, the gasket and joint surfaces must be lubricated for installation.

Mastic joints consist of bitumen and inert fillers. The sealant is applied to the tongue and groove, and provide some flexibility without leaking. Cement joints

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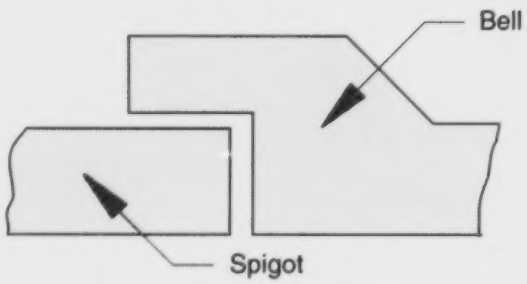
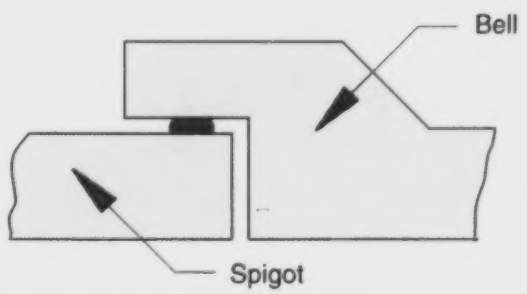
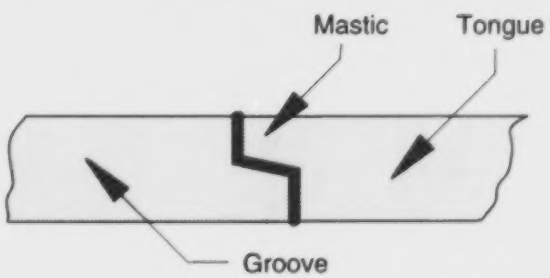


Bell and Spigot Mortar Joint



Bell and Spigot O-Ring Joint



Tongue and Groove Joint with Mastic Sealer

Figure 4-27
RCP Joint Types

consist of cement paste or cement mortar applied to the tongue and groove of the pipe sections. Mortar joints are rigid and care must be taken to eliminate movement after installation.

Combination rubber-mastic bands are used to join non-circular RCP. The bands are installed on the exterior surface of the pipe joint.

Corrugated Metal Pipe (CMP) - Flexibility and long pipe joints, along with ease of installation, gives corrugated metal pipe (CMP) a place in storm sewer construction. Fittings, manholes, and catch basins of any specification can be factory made and delivered to the job ready to be installed. Couplings for CMP (Figure 4-28) are generally of three basic designs; simple flat bands, fully corrugated bands (annular or helical), and a flat band with tooth-like projections, called a "universal" or "dimple band." CMP couplings are normally assembled using a C-clamp to bring the band ends together. This allows easier and quicker installation of the bolts.

Various types of joint sealants and synthetic rubber gaskets can be used for CMP connections in order to obtain maximum water tightness. Asphalt and bituminous coatings can be applied over the galvanized metal for added protection against corrosion. Because CMP is very flexible, bedding and haunching of the pipe is very important.

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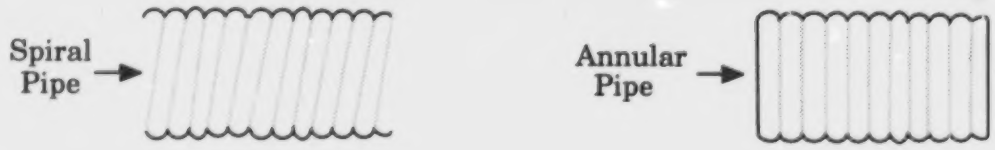
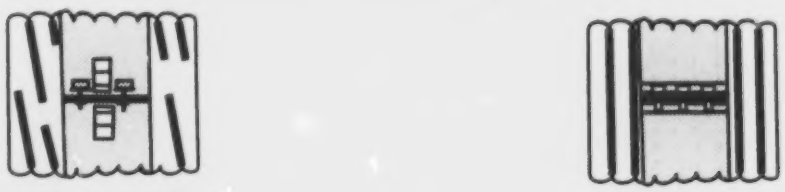
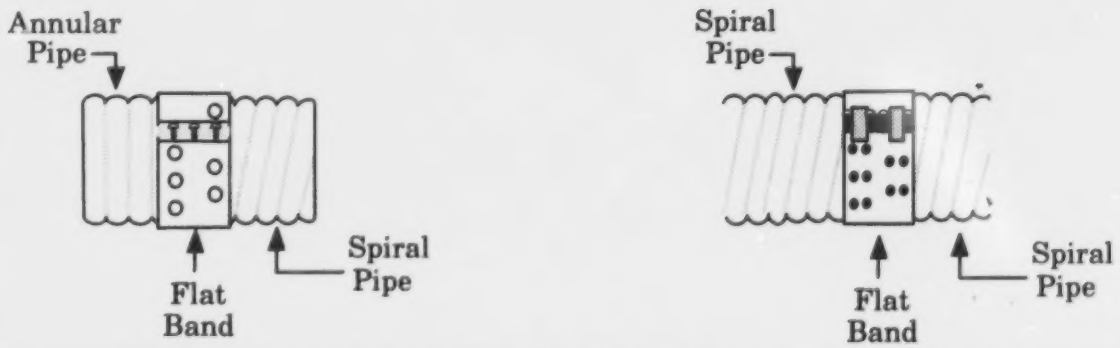
CORRUGATED METAL PIPE



CORRUGATED BANDS



SIMPLE FLAT BANDS



CORRUGATED BANDS WITH RUBBER GASKETS

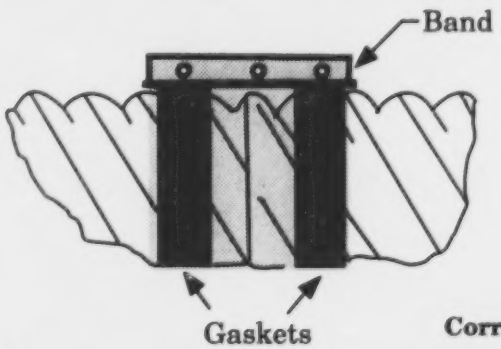


Figure 4-28
Corrugated Metal Pipe Couplers

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Corrugated Polyethylene Pipe (CPP) - Has couplers and fittings much like CMP. Manholes and catch basins used with CPP are usually concrete. CPP is very light and flexible, so care must be taken during haunching and backfill to prevent moving the pipe. Figure 4-29 shows CPP pipe, and Figure 4-30 shows a contoured coupler around a joint.

Figure 4-29
Corrugated Polyethylene Pipe

Figure 4-30
Corrugated Polyethylene Coupler

SUBDRAINS AND SUBSOIL DRAINS

General Overview

Subdrains and subsoil drains are designed to remove excess groundwater. They are installed around buildings, highways, and anywhere where groundwater is a problem. Subdrains are constructed using perforated pipe. Water will seep from the surrounding soil into the perforations and follow the gravity flow slope into the collection or storm drain system. When installed around buildings, as in a foundation drain system, a collection area and pump station may be used to route the water into the storm drain system.

Pipe Types

PolyVinyl Cloride (PVC) is often used in a drain field application. Usually installed using solvent cement joints, the joints will range from 12.5' to 20' length. One type of perforated PVC is shown in Figure 4-31.

Figure 4-31
Perforated PolyVinyl Cloride

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Corrugated Metal Pipe (CMP) is primarily used for groundwater collection systems. Usually perforated at approximately 15° on each side of flow line, the perforations must be installed downwards as shown in Figure 4-32.

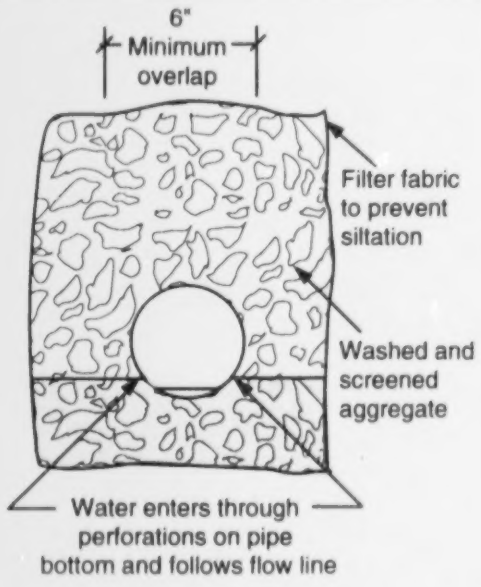

Figure 4-32
Perforated PVC Installation

Corrugated metal pipe is joined with a contoured galvanized metal band and bolts. Joint lengths can commonly be ordered in 15', 18', and 20' sections.

Corrugated Polyethylene Pipe (CPP) is primarily used for groundwater collection systems as shown in (Figure 4-33). Usually perforated entirely around the pipe, there is no specific installation procedures regarding perforations. Joining is performed by polyethylene collars that are contoured to the same shape as the corrugations on the pipe. Care must be taken during installation,

Figure 4-33
Perforated CPP

haunching, and backfill to ensure that the pipe stays on line and grade and that the joining collars do not pull loose. Joint lengths range from 20' to rolls of 100' or longer.

Installation Techniques for Perforated PVC

Normally there are two rows of perforations on PVC pipe. The flow line is the halfway point between these two rows. When installing perforated PVC, perforations should be on the bottom with the flow line dead center, as shown in Figure 4-32.

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The flow line is installed dead center to allow the water to build up evenly to the perforations on the pipe. The water then enters the pipe and runs out along the flow line. If the two rows of perforations were improperly installed facing upwards, silt could collect in the holes and plug them up. Another way to prevent silt from building up inside the pipe is to use a filter cloth. The cloth lets in the water and prevents any debris from entering the pipe. Filter cloths are usually wrapped around the pipe.

Installation Techniques for Perforated CPP

Installation of perforated pipe for subdrains can be accomplished using an excavator or a trenching machine. Corrugated pipe should be bedded and covered with a minimum of 12" of crushed, washed gravel to prevent siltation and clogging of the perforations. Use of a filter fabric to surround the envelope is a common design feature. Figure 4-34 shows a standard subdrain design. During small inch installation, another type of installation procedure can be used. A plow is used to create a ditch. The plow vibrates the dirt, packing it to form the ditch. The pipe is then laid into the ditch and backfilled according to design specifications.

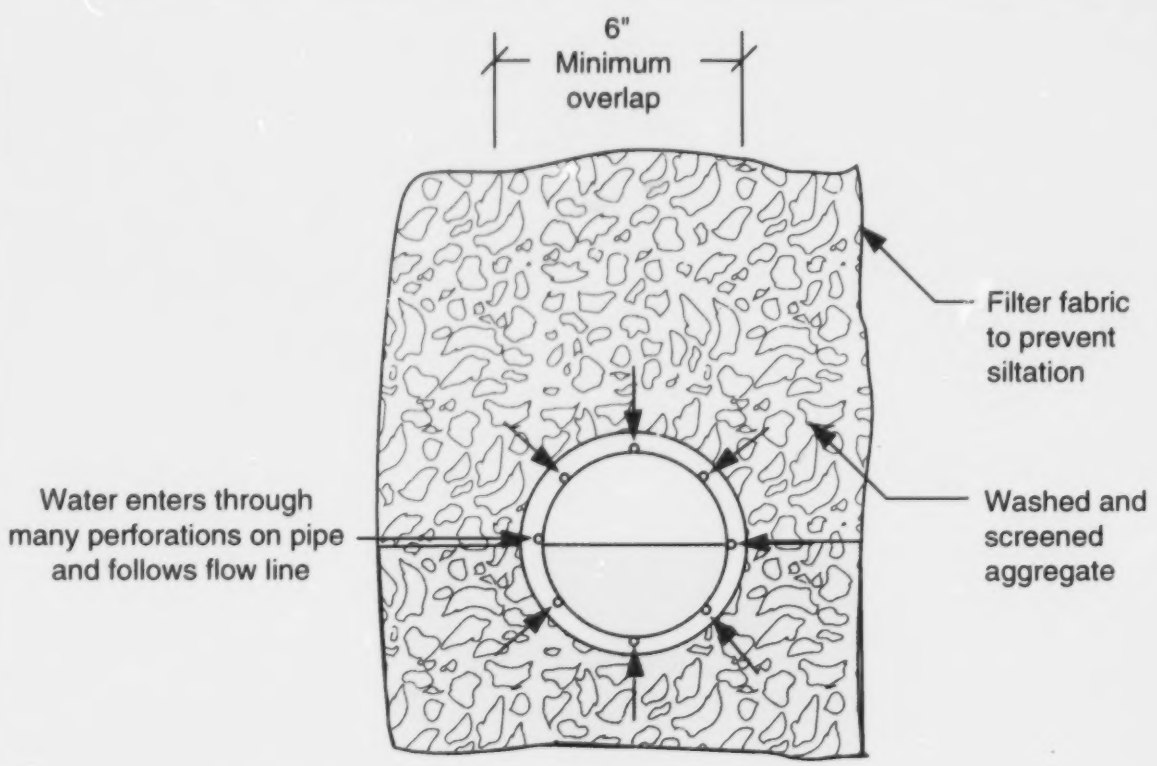

Figure 4-34
Perforated CPP Installation

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NOTES:

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SECTION IV ASSIGNMENT SHEETS

Answer the following sanitary sewer questions:

1. What is the usual allowable tolerance for every joint of sanitary sewer pipe?

2. What can happen if a sewer line is installed at too great a gradient?

3. Name four common pipe types used in sanitary sewer construction.

4. Why is it important to handle clay pipe carefully?

5. List two types of vitrified clay bell ends.

6. What is the length of clay pipe joints?

7. What are the diameters and lengths of manufactured PVC pipe?

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8. Name two different types of material that are used to join PVC pipe joints and fittings.

_____

_____

9. When is a reinforced concrete pipe used in a sanitary sewer system? _____

_____

10. What are the diameters and lengths of RCP?

_____

_____

11. What is the length of ductile iron pipe joints? _____

12. How much bedding material is normally placed under a pipe, if it is required?

_____

13. What should you do to bedding in order to give satisfactory support to the pipe?

_____

14. Debris between the_____ and _____ will cause a leak.

15. How far do you push the spigot into the bell end of a pipe? _____

_____

16. What has to be done to the haunching area in order to keep a pipe from being deformed?

_____

17. Why would you use a T-bar? _____

_____

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18. What is the maximum depth of a lift of haunching material? _____

_____

19. How far apart are manholes placed? Why? _____

_____

20. When are drop inlets installed? _____

_____

21. Why are cleanouts constructed at a 45 degree angle? _____

_____

22. What is the purpose of a lateral? _____

_____

23. What is the required grade for lateral pipe installation? _____

24. What is the most common way to repair gravity flow pipe? _____

_____

25. When repairing concrete pipe 15" in diameter or larger, what part of the bell end is removed on the existing pipe?

_____

26. What is the purpose of a low pressure sewer test? _____

_____

27. Low pressure air tests are used on pipes from _____ inches to _____ inches in diameter.

28. What should you do to a test plug after it has been installed? _____

29. Why are inflatable test plugs dangerous? _____

_____

_____

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30. When is it safe to enter a manhole or remove plugs?

31. Why is it important for an invert to be shaped as smoothly and evenly as possible?

Answer the following storm drain questions:

32. Name five parts of a storm drain system.

33. What are the normal slope tolerances for storm drain pipe joints?

34. What are the three major storm drain pipe types?

35. What are the two types of rubber gaskets used in RCP?

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36. Name three basic coupling designs for RCP.

_____

_____

_____

37. Why is proper bedding and haunching of CMP important? _____

_____

Answer the following subdrain questions:

38. What kind of pipe is used during subdrain installations? _____

_____

39. What lengths of PVC pipe are used for subdrain installations? _____

_____

40. What is the primary use for CMP and CPP? _____

41. How much crushed, washed gravel is placed over perforated CPP? _____

_____

42. Why is the crushed, washed gravel placed over the CPP? _____

_____

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NOTES:

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Appendix A

Glossary of Terms and Abbreviations

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GLOSSARY OF TERMS AND ABBREVIATIONS

AHD: Ahead.

Angle of repose: The greatest angle above the horizontal plane at which base soil will lie without sliding.

Arch: The upper inside section of a pipe.

Asphyxiant: A gas capable of causing death due to oxygen deficiency.

Backfill: The refilling of a trench; or as a noun, the material used to refill a trench.

Backhoe: An excavating machine that is equipped with an articulating boom and a bucket. May have crawler tracks or rubber tires.

Batterboards: A series of horizontal boards spanning the trench, used by the contractor to set the line and grade of the pipe.

Bedding: Sand or fine stone that is placed in the bottom of a trench as a foundation for the pipe.

Bell end or socket: The enlarged end of a joint of pipe. Referred to as the female end.

Bench mark: A surveyors stake or mark at a known elevation. Bench marks are used as reference points to establish other known elevations or control points. These control points are used to establish grade for the construction of sewers.

BK: Back.

BM: Bench Mark.

BOB: Bottom of Bedding.

BOP: Bottom of Pipe.

C: Cut.

CB: Catch basin.

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Center line (℄): The exact center of a structure; in sewer construction used as ℄ of pipe or ℄ of a manhole.

Choke: To pass the end of a wire rope sling through the eye of the other end and pull on it until it fastens securely around the object that is to be lifted.

Choker: Another term for wire rope sling.

℄: Center line.

Class of pipe: Strength of pipe determined by ASTM. In concrete pipe, class is in reference to size and amount of steel in pipe wall, thickness of wall remains the same. Exceptions are in tongue and groove pipe, non-reinforced, and extra strength pipe. In other pipe class is determined by wall thickness.

CMCP: Corrugated metal culvert pipe.

CMPA: Corrugated metal pipe arch.

CO: Clean out.

Compact soil: Soil that is hard and stable in appearance. Compact soil can be readily indented by the thumb, but penetrated only with great difficulty.

Confined area: Any space that lacks ventilation; usually the space is larger in area than the point of entry.

Coupling: The act of joining the bell end and spigot end together to make a joint.

Cribbing: Pieces of lumber used to support and stabilize an object, such as cross braces and wales used in timber shoring.

CUL: Culvert.

Cut: The vertical distance from the top of an offset stake to the invert or flowline of a pipe.

Cut Sheet: A printed form furnished by the engineer giving the computed cut or elevation from the offset stake to the pipe invert at

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specific stations. Cuts may also be found on witness stakes next to the offset hubs.

Deep-well systems: A means for dewatering the ground around a trench. In a line parallel to the trench, pipe casing with screens are driven into the ground to a level below the trench floor. Electric submersible pumps lowered into the casings continually dewater the work area. The water is collected in a header and is discharged at a point distant from the site.

Dewatering: Removing water from the work area.

DI: Drain inlet.

Diaphragm pump: A positive displacement pump that has a diaphragm instead of a piston; an excellent device for moving water in which foreign matter is suspended.

Disturbed soil: Ground that has been previously excavated.

DMH: Drop manhole.

Double-head nail: A nail that is provided with a flange close to the head. The flange prevents the nail from being driven all of the way into lumber. Removal is easy because the head remains exposed.

Driving home pipe: Connecting together pieces of slip joint pipe. Also called stabbing the pipe.

Drop manhole: A manhole with sewers coming in at different elevations of at least 2.0 feet or more in height.

EL: Elevation.

Engineer's hubs: Stakes placed on a utility construction site by a layout crew. Symbols on the stakes tell the contractor where and how deep he should dig.

EOP: End of Pipe.

Exposed utilities: Gas mains, water mains, electrical conduits, etc. that are exposed but unbroken during a trench digging operation.

Eye of the sling: A loop formed into the end of a wire rope.

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F: Fill.

Fernco: A rubber coupling used to repair or adapt two pipes together by use of bands as a tightening device.

FG: Finish grade.

Fissure: A narrow opening in the ground; a crack of some length and considerable depth.

FL: Flowline.

Flag stake: A piece of lath with a colored ribbon attached to mark the location of an engineer's hub. On the stake will appear information about the center line and depth of the trench.

Flexible conduit or pipe: Is capable of bending or flexing. Examples are corrugated metal, truss pipe (ABS), and plastic pipe (ABS, PVC). The trench load on this type of pipe is transmitted throughout the entire circumference of the pipe.

FM: Force main.

Free-standing time: The period of time during which trench walls remain standing unsupported after excavation.

Front end loader: A rubber tire or crawler equipped machine with a movable bucket at one end.

Frost line: The depth to which frost penetrates the soil.

G: Grade.

Gas main: Generally a large diameter pipeline that carries natural gas under the streets.

Gas service line: A small diameter pipe that connects the consumer with the gas main under the street.

Grade: The slope of a line in reference to a horizontal plane.

Grade pole: A wood or fiberglass pole that is either cut to a certain length or provided with markings. It is used by workmen when they are setting pipes on grades.

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Grease can and brush: A can of lubricant that is used for joining slip-joint pipe and the brush which the lubricant is applied.

Header: A large diameter pipe with inlets for suction hoses and a connection for the suction side of a pipe.

Height of instrument (HI): The distance measured vertically from center line of transit to a reference point, such as a bench mark, a pipe flowline, or a laser.

Horizontal: Is parallel to the horizon or level. Horizontal measurements are usually called stations.

HW: Head wall.

HYD: Hydrant.

Hydrostatic pressure: The force generated by a liquid.

INL: Inlet.

Inside diameter (I.D.): The dimension or size measured on the inside of the pipe walls (i.e. 8", 10", 12" etc.).

Interceptor sewers: Are of larger sizes and receive sewage from trunk sewers and mains. The three sewers mentioned; trunk, main and interceptor are at times used indiscriminately.

INV: Invert.

Invert or flowline: The lowest section or part of the interior diameter of a pipe.

Joint of pipe: One length or piece of pipe.

Kiln dried (lumber): Lumber that is artificially dried in an oven-like structure.

L: Laser.

Laser blower: A motor driven fan (usually 12 volt) used by contractors to purge a pipe of stale air and fumes when a laser instrument is being used.

Laser target: A square or rectangular plastic device used in conjunction with a laser instrument to set the line and grade of pipe.

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Lateral sewers:	Are normally 8" to 12" diameter pipes laid in streets and collect sewage from individual house services and empty into trunk, main, or interceptor sewers.
Loam:	A combination of sand and clay.
Lower explosive limit (LEL):	In a range of percentages, the point at which a mixture of flammable gas and air will not ignite because there is an insufficient concentration of the gas.
LT:	Left.
Manhole:	An access way to sewer pipes; an opening used for maintenance and inspection.
Manifold:	A pipe fitting with several inlets and/or outlets.
Methane gas:	The chief component of natural gas; colorless, odorless and flammable.
MH:	Manhole.
Non-pressure pipe:	A conduit to convey materials by gravity at design grades or slope; or gravity flow from a higher elevation to a lower elevation.
OD:	Outside diameter.
Offset:	The distance (in feet) measured perpendicular from an engineer's hub to the pipeline. On witness stakes offset is usually written with the offset distance inside a circle.
OSHA:	The Occupational Safety and Health Administration, a division of the U.S. Department of Labor.
Outside diameter (O.D.):	The dimension measured to the outside of the pipe walls.
Parallel trench:	A previously excavated and backfilled trench close to and paralleling the trench being dug.
Percent of grade:	The amount of slope of a pipe from one point to another. This slope can also be expressed as rate per foot.

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Pipe string:	Lengths of pipe laid parallel to the trench lip in preparation for being joined and buried.
Pneumatic shoring:	Trench shores or jacks with movable parts that are operated by the action of compressed gas.
Pressure pipe:	A conduit to convey material under pressure from one point to another (water systems, force mains, gas lines).
Profile:	A job blueprint that shows sectional elevation.
RCCP:	Reinforced concrete culvert pipe.
RCP:	Reinforced concrete pipe.
Release tool:	A hand held device that is used to depressurize hydraulic shoring.
Replacement sewer line:	A new pipeline installed adjacent to an existing line for the purpose of taking over the original line's function.
Right-of-way:	A strip of land temporarily granted to the contractor for him to perform his work.
Rigid conduit or pipe:	Is inflexible, stiff, and does not bend. Examples are concrete, vitrified clay, asbestos cement (transite) and ductile iron. The trench load on this type of pipe is transmitted directly to the bedding beneath the pipe.
Rise:	The difference in feet from one known point to another known point.
RP:	Reference Point.
RT:	Right.
Running soil:	Loose, freely flowing soil, such as sugar sand.
R/W:	Right of way.
S:	Slope.
Sanitary sewer:	A buried pipeline that carries sewage.

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Saturated soil: Soil that contains an unusually high quantity of water. Easily identified because of seepage.

Scab: A short piece of lumber generally used to construct a crib used in timber shoring.

Screw jack: A trench shore or jack with interchangeable threaded parts. The threading allows the jack to be lengthened or shortened.

Select fill: Soil that is specially chosen to replace that which has been excavated.

Self dumping valve: A spring loaded valve that is part of a pneumatic shoring system. When the valve handle is depressed, the system is pressurized. When the valve handle is relaxed, pressure is released.

Service or connection sewers: Are normally 4" and 6" diameter pipes that collect sewage from houses and other buildings and empty into lateral sewers.

SG: Subgrade.

Shackle: A u-shaped round piece of steel that is provided with a pin or threaded bolt. Used to join rigging devices.

Shear: In this case, force caused stress that results in a section of trench wall sliding from the main body of earth.

Sheeting: Generally speaking, wood planks and wood panels that support trench walls when held in place with shoring.

Shoring: The general term used for lengths of timber, screwjacks and other devices that can be used to hold sheeting against trench walls. Individual supports are called shores, crossbraces, and struts.

Signal man: A person who gives or relays commands to a heavy equipment operator.

Skip shoring: The procedure for supporting trench walls with uprights and shores at spaced intervals.

Sliding choker: A steel hook provided on a wire rope sling. The hook enables the sling to adjust for loads of various sizes and shapes.

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Slough-in: The collapse of a portion of trench wall in such a fashion that an over hang remains.

Snatch block: A wood or steel shell, single pulley block that can be opened on one side to accept a rope or cable.

Soil typing: Determining properties of soil, such as strength, in-place unit weight, compressibility, and permeability.

Solid sheeting: The procedure for supporting trench walls with sections of sheeting butted together.

S.O.P.: Standard operating procedure.

Spigot end: The straight end of a joint of pipe, usually bevelled to fit into the bell end of another joint. Referred to as the male end.

Spoil pile: The heap of material excavated from a trench.

Spot bracing: Another term for skip shoring.

Spot dewatering: The technique of drawing water from localized portions of the ground around a trench.

Spray deflector: The plate on the end of the release tool that deflects hydraulic fluid lost during the depressurizing operation.

Springline: The middle of a pipe.

STA: Station.

Station: A measured distance from a point of beginning at 0+00. If a manhole is at station 17+80, it means the manhole is 1,780 feet from the beginning point.

Story pole: See Grade pole.

String lines: Strings placed on one side of and parallel to the trench. Used to determine grade.

Strongback: See Upright

Sump: A pit dug at a low point in the trench floor; it serves to keep the screened end of the suction hose below the water level.

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Tag lines: Hand held lengths of rope used to steady or move an object that is being hoisted or lowered.

Tension cracks: Cracks in the ground adjacent to the trench. Tension cracks indicate that the ground has shifted and should be considered as warning signs.

Tight sheeting: Another term used for solid sheeting.

TOP: Top of Pipe.

Trash pump: A centrifugal or diaphragm pump designed to move water that contains mud, stones and other debris.

Trench box: A steel, fiberglass or aluminum structure that is placed in a trench to protect workmen from the collapse of trench walls, and which can be moved along as work progresses.

Trench lip: The edge of a trench.

Trench load: The weight of the backfill material imposed on the pipe.

Trench width: The maximum width permitted within one foot above top of the pipe.

Tripping hazards: Debris, tools, equipment, and anything else that may cause a person to stumble on a construction site.

Trunk sewer main: Is normally larger than 12" diameter pipe. Often located of streets in valleys or low areas, they receive sewage from laterals and empty into interceptors.

Upper explosive limit (UEL): In a range of percentages, the point at which a mixture of flammable gas and air will not explode because there is not sufficient oxygen.

Uprights: Generally speaking, planks that are held in place against sections of sheeting with shores. They distribute forces exerted by trench walls and counterforces exerted by shores over wider areas of the sheeting.

USGS: (United States Geological Survey) A survey made by the federal government to establish exact coordinates and elevations above the mean sea level throughout the United States.

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Ventilating the trench:	Using a powered fan to replace stale or contaminated air in a trench with fresh air.
Vertical:	Is perpendicular to the horizon or plumb. Vertical measurements are usually called grades or elevations.
Virgin soil:	Ground that has never been excavated.
Wales:	Braces that are placed horizontally against sheeting. Wales transmit loading from sheeting to shores. Also called walers or stringers.
Wall:	The side of a trench from the lip to the floor. Also called the face.
Wall thickness:	The measured dimension of one wall of the pipe.
Water main:	Generally a large diameter, water carrying pipeline that is laid under the street.
Water service line:	A small diameter pipe that connects the consumer to the water main.
Water table:	The upper limit of a portion of the ground that is wholly saturated with water from underground sources. May be very near the surface or deep in the ground.
Well casing:	A large diameter pipe that is used in deep well systems.
Well-point system:	A series of pipes driven or jetted into the ground along a trench for the purpose of dewatering the work area. Water is drawn through the pipes into a header and finally into the suction side of a pump.
Wire rope:	An extremely strong rope made of strands of wire. Also called cable.
Wire rope sling:	A lifting device made of wire rope. An eye is provided at both ends.
WW:	Wing wall.

NOTES:

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Appendix B

U.S. Occupational Safety and Health Administration

Construction Standard for Excavations

(29 CFR Part 1926.650-.652)
Subpart P

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§1926.650 Scope, application, and definitions applicable to this subpart.

(a) Scope and application. This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches.

(b) Definitions applicable to this subpart.

Accepted engineering practices means those requirements which are compatible with standards of practice required by a registered professional engineer.

Aluminum Hydraulic Shoring means a pre-engineered shoring system comprised of aluminum hydraulic cylinders (crossbraces) used in conjunction with vertical rails (uprights) or horizontal rails (walers). Such system is designed, specifically to support the sidewalls of an excavation and prevent cave-ins.

Bell-bottom pier hole means a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

Benching (Benching system) means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in means the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Cross braces means the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Excavation means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Faces or sides means the vertical or inclined earth surfaces formed as a result of excavation work.

Failure means the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere means an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Kickout means the accidental release or failure of a cross brace.

Protective system means a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Ramp means an inclined walking or working surface that is used to gain access to one point from another, and is constructed from earth or from structural materials such as steel or wood.

Registered Professional Engineer means a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

Sheeting means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

Shield (Shield system) means a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either premanufactured or job-built in accordance with § 1926.652 (c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) means a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

Sides. See "Faces."

Sloping (Sloping system) means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Stable rock means natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Structural ramp means a ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock are not considered structural ramps.

Support system means a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation.

Tabulated data means tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Trench box. See "Shield."

Trench shield. See "Shield."

Uprights means the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely

spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

§ 1926.651 General requirements.

(a) *Surface encumbrances.* All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported, as necessary, to safeguard employees.

(b) *Underground installations.* (1) The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.

(2) Utility companies or owners shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of actual excavation. When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used.

(3) When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means.

(4) While the excavation is open, underground installations shall be protected, supported or removed as necessary to safeguard employees.

(c) *Access and egress* - (1) Structural ramps. (i) Structural ramps that are used solely by employees as a means of access or egress from excavations shall be designed by a competent person. Structural ramps used for access or egress of equipment shall be designed by a competent person qualified in structural design, and shall be constructed in accordance with the design.

(ii) Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.

(iii) Structural members used for ramps and runways shall be of uniform thickness.

(iv) Cleats or other appropriate means used to connect runway structural members shall be attached to the bottom of the runway or shall be attached in a manner to prevent tripping.

(v) Structural ramps used in lieu of steps shall be provided with cleats or other surface treatments on the top surface to prevent slipping.

(2) *Means of egress from trench excavations.* A stairway, ladder, ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

(d) *Exposure to vehicular traffic.* Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable

garments marked with or made of reflectorized or high-visibility material.

(e) *Exposure to falling loads.* No employee shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of vehicles being loaded or unloaded when the vehicles are equipped, in accordance with § 1926.601 (b)(6), to provide adequate protection for the operator during loading and unloading operations.

(f) *Warning system for mobile equipment.* When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, hand or mechanical signals, or stop logs. If possible, the grade should be away from the excavation.

(g) *Hazardous atmospheres* - (1) Testing and controls. In addition to the requirements set forth in subparts D and E of this part (29 CFR 1926.50-1926.107) to prevent exposure to harmful levels of atmospheric contaminants and to assure acceptable atmospheric conditions, the following requirements shall apply:

(i) Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

(ii) Adequate precaution shall be taken to prevent employee exposure to atmospheres containing less than 19.5 percent oxygen and other hazardous atmospheres. These precautions include providing proper respiratory protection or ventilation in accordance with subparts D and E of this part respectively.

(iii) Adequate precautions shall be taken such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20 percent of the lower flammable limit of the gas.

(iv) When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

(2) *Emergency rescue equipment.* (i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, shall wear a harness with a life-line securely attached to it. The lifeline shall be separate from any line used to handle materials, and shall be individually attended at all times while the employee wearing the lifeline is in the excavation.

(h) *Protection from hazards associated with water accumulation.* (1) Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is

accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation. The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.

(2) If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations shall be monitored by a competent person to ensure proper operation.

(3) If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains will require an inspection by a competent person and compliance with paragraphs (h)(1) and (h)(2) of this section.

(i) *Stability of adjacent structures.* (1) Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.

(2) Excavation below the level of the base or footings of any foundation or retaining wall that could be reasonably expected to pose a hazard to employees shall not be permitted except when:

(i) A support system, such as underpinning, is provided to ensure the safety of employees and the stability of the structure; or

(ii) The excavation is in stable rock; or

(iii) A registered professional engineer has approved the determination that the structure is sufficiently removed from the excavation so as to be unaffected by the excavation activity; or

(iv) A registered professional engineer has approved the determination that such excavation work will not pose a hazard to employees.

(3) Sidewalks, pavements, and appurtenant structure shall not be undermined unless a support system or another method of protection is provided to protect employees from the possible collapse of such structures.

(j) *Protection of employees from loose rock or soil.* (1) Adequate protection shall be provided to protect employees from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection shall consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection.

(2) Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such materials or equipment at least 2 feet (.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

(k) *Inspections.* (1) Daily inspections of excavations, the adjacent areas, and

protective systems shall be made by a competent person for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. An inspection shall be conducted by the competent person prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rainstorm or other hazard increasing occurrence. These inspections are only required when employee exposure can be reasonably anticipated.

(2) Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

(1) *Fall protection.* (1) Where employees or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided.

(2) Adequate barrier physical protection shall be provided at all remotely located excavations. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, pits, shafts, etc., shall be backfilled.

§ 1926.652 Requirements for protective systems.

(a) *Protection of employees in excavations.* (1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

(i) Excavations are made entirely in stable rock; or

(ii) Excavations are less than 5 feet (1.52 m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

(b) *Design of sloping and benching systems.* The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3); or, in the alternative, paragraph (b)(4), as follows:

(1) *Option (1) - Allowable configurations and slopes.* (i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in Appendix B to this subpart.

(2) *Options (2) - Determination of slopes and configurations using Appendices A and B.* Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and

requirements set forth in appendices A and B to this subpart.

(3) *Option (3) - Designs using other tabulated data.* (i) Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and shall include all of the following:

(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4) - Design by a registered professional engineer.* (i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include at least the following:

(A) The magnitude of the slopes that were determined to be safe for the particular project;

(B) The configurations that were determined to be safe for the particular project; and

(C) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

(c) Design of support systems, shield systems, and other protective systems. Designs of support systems, shield systems, and other protective systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (c)(1); or, in the alternative, paragraph (c)(2); or, in the alternative, paragraph (c)(3); or, in the alternative, paragraph (c)(4) as follows:

(1) *Option (1) - Designs using appendices A, C and D.* Designs for timber shoring in trenches shall be determined in accordance with the conditions and requirements set forth in appendices A and C to this subpart. Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

(2) *Option (2) - Designs Using Manufacturer's Tabulated Data.* (i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.

(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only

be allowed after the manufacturer issues specific written approval.

(iii) Manufacturer's specifications, recommendations, and limitations, and manufacturer's approval to deviate from the specifications, recommendations, and limitations shall be in written form at the jobsite during construction of the protective system. After that time this data may be stored off the jobsite, but a copy shall be made available to the Secretary upon request.

(3) *Option (3) - Designs using other tabulated data.* (i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and include all of the following:

(A) Identification of the parameters that affect the selection of a protective system drawn from such data;

(B) Identification of the limits of use of the data;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data, which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4) - Design by a registered professional engineer.* (i) Support systems, shield systems, and other protective systems not utilizing Option 1, Option 2, or Option 3, above, shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include the following:

(A) A plan indicating the sizes, types, and configurations of the materials to be used in the protective system; and

(B) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite during construction of the protective system. After that time, the design may be stored off the jobsite, but a copy of the design shall be made available to the Secretary upon request.

(d) *Materials and equipment.* (1) Materials and equipment used for protective systems shall be free from damage or defects that might impair their proper function.

(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service, and shall be evaluated and approved by a registered professional engineer before being returned to service.

(e) *Installation and removal of support* - (1) *(General).* (i) Members of support systems shall be securely

connected together to prevent sliding, falling, kickouts, or other predictable failure.

(ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.

(iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.

(iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.

(v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in on the sides of the excavation.

(vi) Backfilling shall progress together with the removal of support systems from excavations.

(2) *Additional requirements for support systems for trench excavations.* (i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

(ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

(f) *Sloping and benching systems.* Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

(g) *Shield systems* - (1) *General.* (i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.

(ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.

(iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

(iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.

(2) *Additional requirement for shield systems used in trench excavations.* Excavations of earth material to a level not greater than 2 feet (.61 m) below the bottom of a shield shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

Appendix A to Subpart P

Soil Classification

(a) *Scope and application* - (1) Scope. This appendix describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The appendix contains definitions, sets forth

requirements, and describes acceptable visual and manual tests for use in classifying soils.

(2) *Application.* This appendix applies when a sloping or benching system is designed in accordance with the requirements set forth in § 1926.652 (b)(2) as a method of protection for employees from cave-ins. This appendix also applies when timber shoring for excavations is designed as a method of protection from cave-ins in accordance with appendix C to subpart P of part 1926, and when aluminum hydraulic shoring is designed in accordance with appendix D. This Appendix also applies if other protective systems are designed and selected for use from data prepared in accordance with the requirements set forth in § 1926.652 (c), and the use of the data is predicated on the use of the soil classification system set forth in this appendix.

(b) *Definitions.* The definitions and examples given below are based on, in whole or in part, the following: American Society for Testing Materials (ASTM) Standards D653-85 and D2488; the Unified Soils Classification System, The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS-121.

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

Dry soil means soils that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

Soil classification system means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater or is free seeping.

Type A means cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

(i) The soil is fissured; or

(ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or

(iii) The soil has been previously disturbed; or

(iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or

(v) The material is subject to other factors that would require it to be classified as a less stable material.

Type B means:

(i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or

(ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silty loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.

(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.

(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

(v) Dry rock that is not stable; or

(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C means:

(i) Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or

(ii) Granular soils including gravel, sand, and loamy sand; or

(iii) Submerged soil or soil from which water is freely seeping; or

(iv) Submerged rock that is not stable, or

(v) Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

Unconfined compressive strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Wet soil means soils that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated. Granular material

that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

(c) *Requirements* - (1) Classification of soil and rock deposits. Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.

(2) *Basis of classification.* The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses shall be conducted by a competent person using tests described in paragraph (d) below, or in other recognized methods of soil classification and testing such as those adopted by the America Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

(3) *Visual and manual analyses.* The visual and manual analyses, such as those noted as being acceptable in paragraph (d) of this appendix, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.

(4) *Layered systems.* In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

(5) *Reclassification.* If, after classifying a deposit, the properties, factors, or conditions affecting the classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

(d) *Acceptable visual and manual tests.*- (1) *Visual tests.* Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

(i) Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

(ii) Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

(iii) Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

(iv) Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

(v) Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

(vi) Observe the area adjacent to the excavation and the sides of the opened

excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

(vii) Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

(2) *Manual tests.* Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

(i) *Plasticity.* Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1/8-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of 1/8-inch thread can be held on one end without tearing, the soil is cohesive.

(ii) *Dry strength.* If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

(iii) *Thumb penetration.* The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation D2488 - "Standard Recommended Practice for Description of Soils (Visual - Manual Procedure).") Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

(iv) *Other strength tests.* Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shearvane.

(v) *Drying test.* The basic purpose of the drying test is to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

(A) If the sample develops cracks as it dries, significant fissures are indicated.

(B) Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as an unfissured cohesive material and the unconfined compressive strength should be determined.

(C) If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

Appendix B to Subpart P

Sloping and Benching

(a) *Scope and application.* This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations for cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in § 1926.652 (b)(2).

(b) *Definitions.*

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

(c) *Requirements* - (1) *Soil classification.* Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

(2) *Maximum allowable slope.* The maximum allowable slope for a soil or rock deposit shall be determined from Table B-1 of this appendix.

(3) *Actual slope.* (i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least 1/2 horizontal to one vertical (1/2H:1V) less steep than the maximum allowable slope.

(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with § 1926.651 (i).

(4) *Configurations.* Configurations of sloping and benching systems shall be in accordance with Figure B-1.

Table B-1 Maximum Allowable Slopes	
SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V) [1] FOR EXCAVATIONS LESS THAN 20 FEET DEEP [3]
STABLE ROCK TYPE A [2] TYPE B TYPE C	VERTICAL (90°) 3/4:1 (53°) 1:1 (45°) 1 1/2:1 (34°)

NOTES:

1. Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.

2. A short-term maximum allowable slope of 1/2 H: 1 V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth.
   Short-term maximum allowable slopes for excavations greater than 12 feet (3.67m) in depth shall be 3/4 H: 1 V (53°).

3. Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

Slope Configurations

(All slopes stated below are in the horizontal to vertical ratio)

B-1.1 Excavations made in Type A soil.

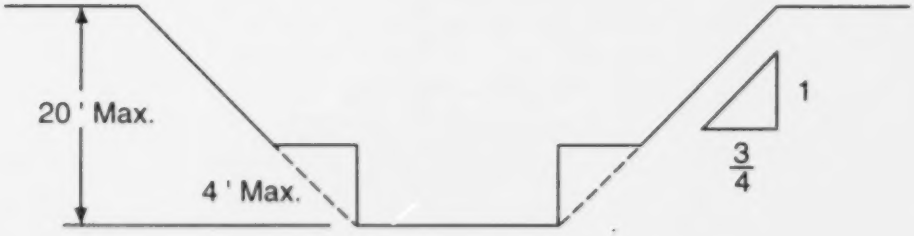
1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 3/4:1

Simple Slope-General

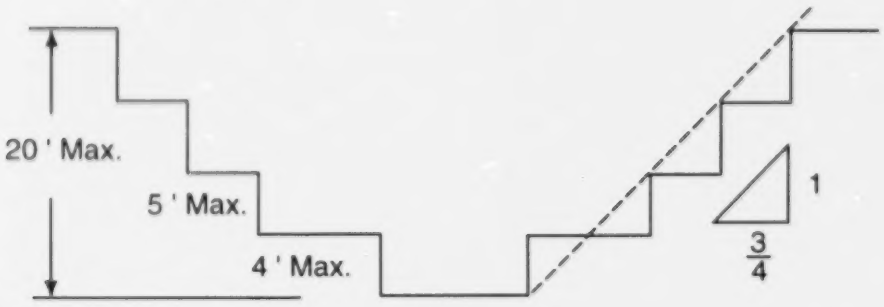
Exception: Simple slope excavations which are open 24 hours or less (short term) and which are 12 feet or less in depth shall have a maximum allowable slope of 1/2:1.

Simple Slope-Short Term

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 3/4 to 1 and maximum bench dimensions as follows:

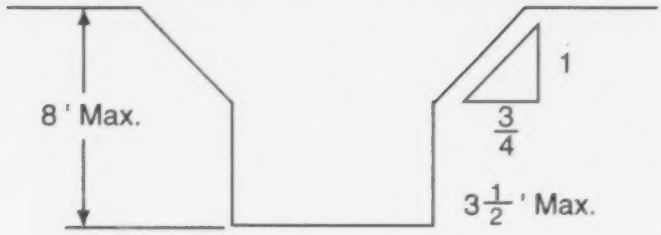


Simple Bench



Multiple Bench

3. All excavations 8 feet or less in depth which have unsupported vertically sided lower portions shall have a maximum vertical side of 3 1/2 feet.

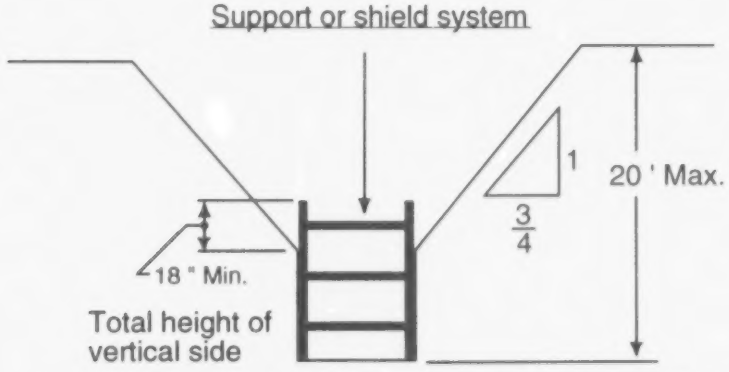


Unsupported Vertically Sided Lower Portion - Maximum 8 Feet in Depth

All excavations more than 8 feet but not more than 12 feet in depth which have unsupported vertically sided lower portions shall have maximum allowable slope of 1:1 and maximum vertical side of 3 1/2 feet.

Unsupported Vertically Sided Lower Portion - Maximum 12 Feet in Depth

All excavations 20 feet or less in depth which have vertically sided lower portions that are supported or shielded shall have maximum allowable slope of 3/4:1. The support or shield system must extend at least 18 inches above the top of the vertical side.



Supported or Shielded Vertically Sided Lower Portion

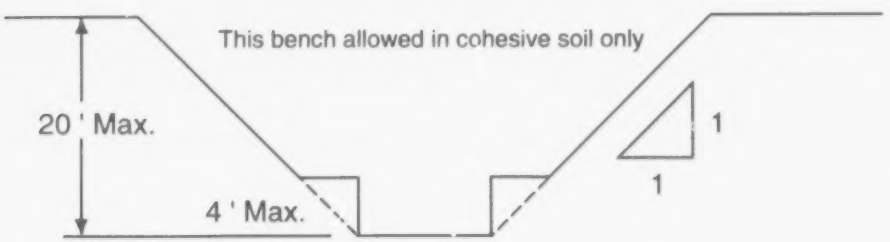
4. All other simple slope, compound slope, and vertically sided lower portion excavations shall be in accordance with the other options permitted under § 1926.652(b).

B-1.2 Excavations Made in Type B Soil

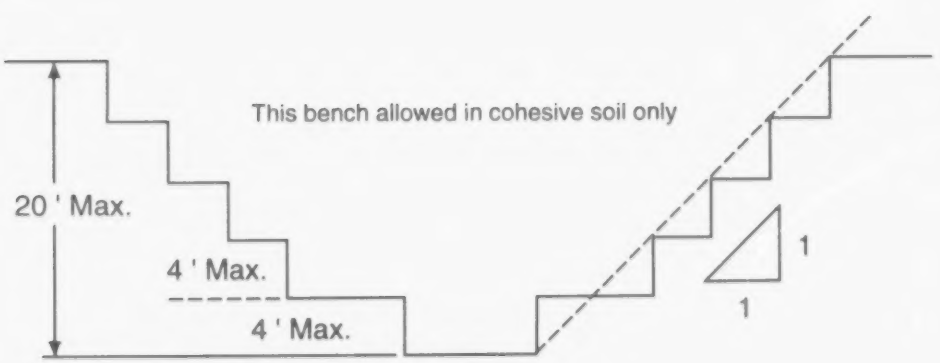
1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1.

Simple Slope

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1 and maximum bench dimensions as follows:

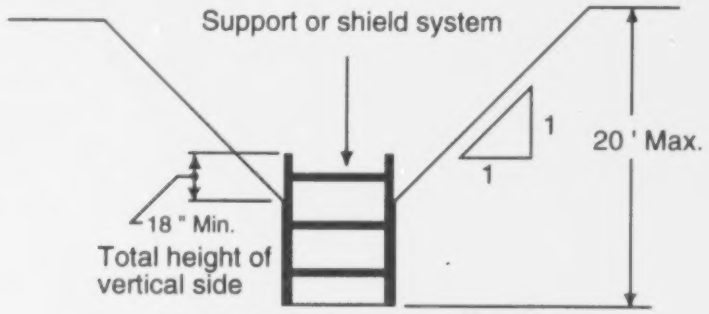


Simple Bench



Multiple Bench

3. All excavations 20 feet or less in depth which have vertical sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1:1.



Vertically Sided Lower Portion

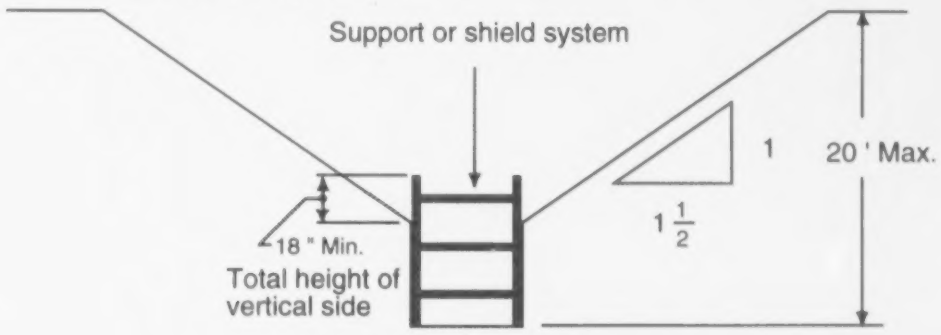
4. All other sloped excavations shall be in accordance with the other options permitted in §1926.652(b).

B-1.3 Excavations Made in Type C Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1 1/2:1.

Simple Slope

2. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1 1/2:1.

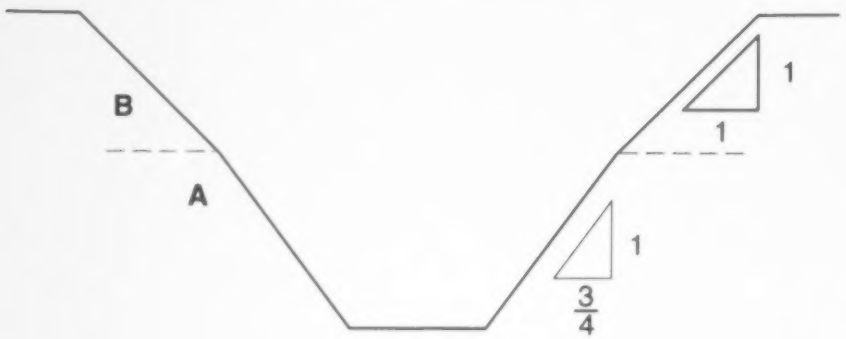


Vertically Sided Lower Portion

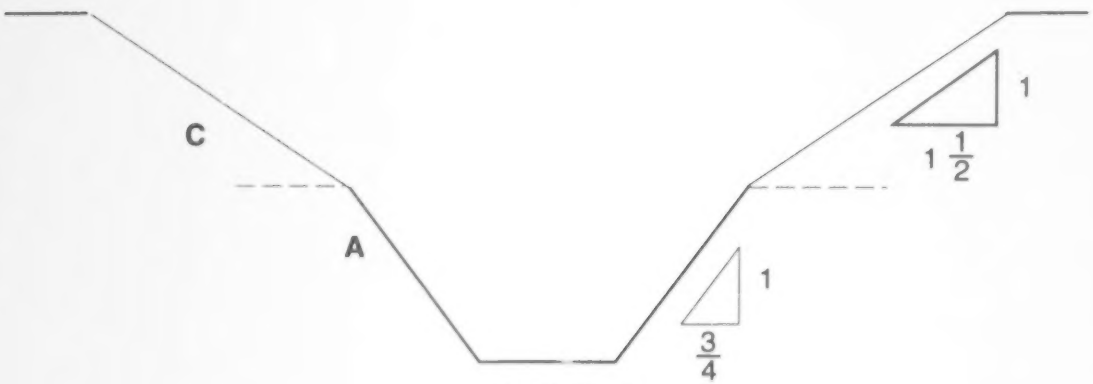
3. All other sloped excavations shall be in accordance with the other options permitted in §1926.652(b).

B-1.4 Excavations Made in Layered Soils

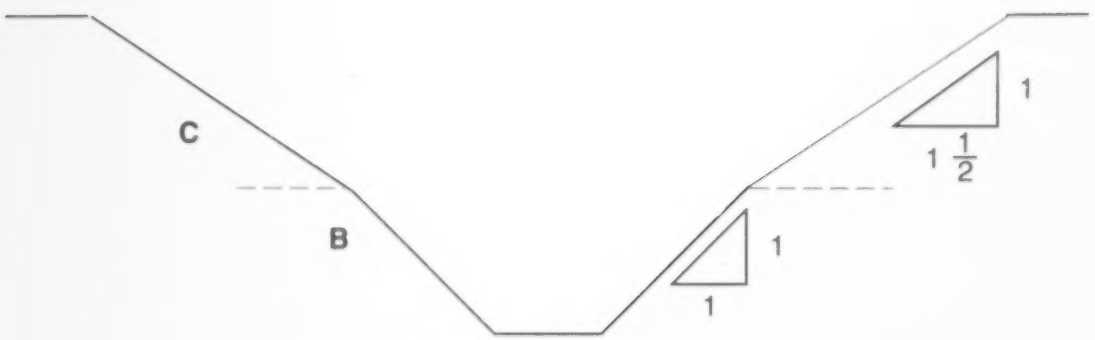
1. All excavations 20 feet or less in depth made in layered soils shall have a maximum allowable slope for each layer as set forth below.



B OVER A

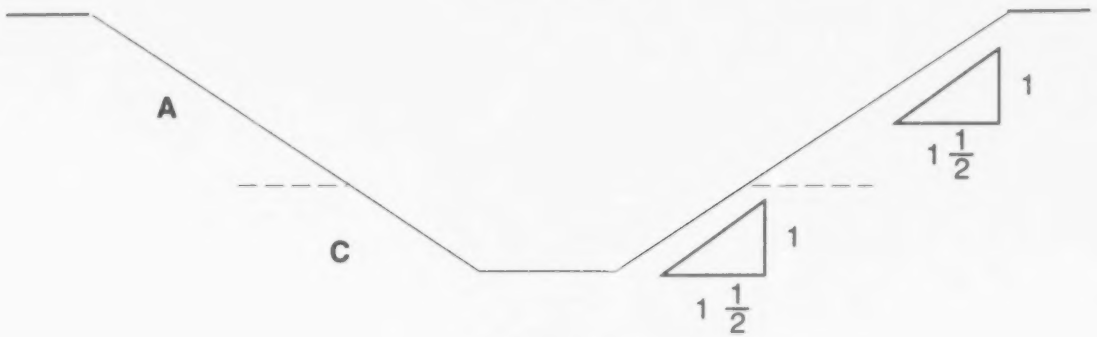


C OVER A

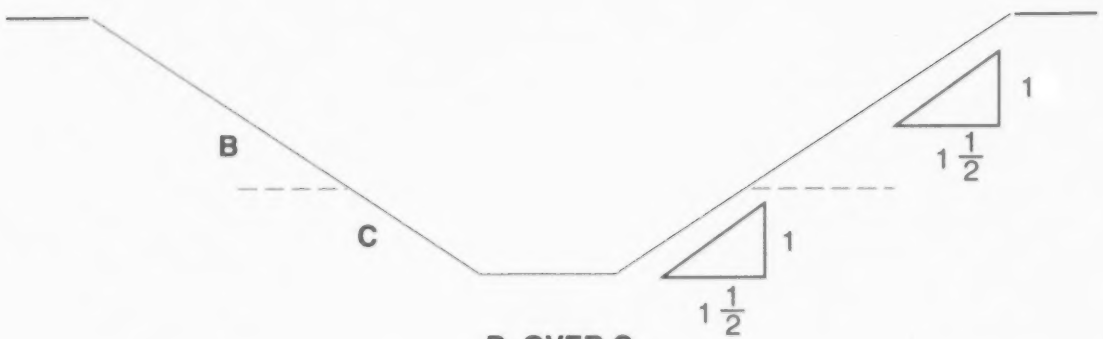


C OVER B

A OVER B



A OVER C



B OVER C

2. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

Appendix C to Subpart P

Timber Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used when timber shoring is provided as a method of protection from cave-ins in trenches that do not exceed 20 feet (6.1 m) in depth. This appendix must be used when design of timber shoring protective systems is to be performed in accordance with § 1926.652 (c)(1). Other timber shoring configurations; other systems of support such as hydraulic and pneumatic systems; and other protective systems such as sloping, benching, shielding, and freezing systems must be designed in accordance with the requirements set forth in § 1926.652 (b) and § 1926.652 (c).

(b) *Soil Classification.* In order to use the data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of this part.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables C-1.1, C-1.2, and C-1.3, and Tables C-2.1, C-2.2, and C-2.3 following paragraph (g) of the appendix. Each table presents the minimum sizes of timber members to use in a shoring system, and each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. The data is arranged to allow the user the flexibility to select from among several acceptable configurations of members based on varying the horizontal spacing of the crossbraces. Stable rock is exempt from shoring requirements and therefore, no data is presented for this condition.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix, and on the tables themselves.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations regarding Tables C-1.1 through C-1.3 and Tables C-2.1 through C-2.3 are presented in paragraph (g) of this Appendix.

(d) *Basis and limitations of the data.* - (1) Dimensions of timber members. (i) The sizes of the timber members listed in Tables C-1.1 through C-1.3 are taken from the National Bureau of Standards (NBS) report, "Recommended Technical Provisions for Construction Practice in Shoring and Sloping of Trenches and Excavations." In addition, where NBS did not recommend specific sizes of members, member sizes are based on an analysis of the sizes required for use by existing codes and on empirical practice.

(ii) The required dimensions of the members listed in Tables C-1.1 through C-1.3 refer to actual dimensions and not nominal dimensions of the timber. Employers wanting to use nominal size shoring are directed to Tables C-2.1 through C-2.3, or have this choice under § 1926.652 (c)(3), and are referred to The Corps of Engineers, The Bureau of Reclamation or data from other acceptable sources.

(2) *Limitation of application.* (i) It is not intended that the timber shoring specification apply to every situation that may be experienced in the field. This

data was developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be designed as specified in § 1926.652 (c).

(ii) When any of the following conditions are present, the members specified in the tables are not considered adequate. Either an alternate timber shoring system must be designed or another type of protective system designed in accordance with § 1926.652.

(A) When loads imposed by structures or by stored material adjacent to the trench weigh in excess of the load imposed by a two-foot soil surcharge. The term "adjacent" as used here means the area within a horizontal distance from the edge of the trench equal to the depth of the trench.

(B) When vertical loads imposed on cross braces exceed a 240-pound gravity load distributed on a one-foot section of the center of the crossbrace.

(C) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(D) When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables.* The members of the shoring system that are to be selected using this information are the cross braces, the uprights, and the wales, where wales are required. Minimum sizes of members are specified for use in different types of soil. There are six tables of information, two for each soil type. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is then made. The selection is based on the depth and width of the trench where the members are to be installed and, in most instances, the selection is also based on the horizontal spacing of the crossbraces. Instances where a choice of horizontal spacing of crossbracing is available, the horizontal spacing of the crossbraces must be chosen by the user before the size of any member can be determined. When the soil type, the width and depth of the trench, and the horizontal spacing of the crossbraces are known, the size and vertical spacing of the crossbraces, the size and vertical spacing of the wales, and the size and horizontal spacing of the uprights can be read from the appropriate table.

(f) *Examples to Illustrate the Use of Tables C-1.1 through C-1.3.*

(1) *Example 1.*

A trench dug in Type A soil is 13 feet deep and five feet wide.

From *Table C-1.1*, four acceptable arrangements of timber can be used.

Arrangement #1

Space 4x4 crossbraces at six feet horizontally and four feet vertically.

Wales are not required.

Space 3x8 uprights at six feet horizontally. This arrangement is commonly called "skip shoring."

Arrangement #2

Space 4x6 crossbraces at eight feet horizontally and four feet vertically.

Space 8x8 wales at four feet vertically

Space 2x6 uprights at four feet horizontally.

Arrangement #3

Space 6x6 crossbraces at 10 feet horizontally and four feet vertically.

Space 8x10 wales at four feet vertically.

Space 2x6 uprights at five feet horizontally.

Arrangement #4

Space 6x6 crossbraces at 12 feet horizontally and four feet vertically.

Space 10x10 wales at four feet vertically.

Space 3x8 uprights at six feet horizontally.

(2) *Example 2.*

A trench dug in Type B soil is 13 feet deep and five feet wide. From *Table C-1.2* three acceptable arrangements of members are listed.

Arrangement #1

Space 6x6 crossbraces at six feet horizontally and five feet vertically.

Space 8x8 wales at five feet vertically.

Space 2x6 uprights at two feet horizontally.

Arrangement #2

Space 6x8 crossbraces at eight feet horizontally and five feet vertically.

Space 10x10 wales at five feet vertically.

Space 2x6 uprights at two feet horizontally.

Arrangement #3

Space 8x8 crossbraces at 10 feet horizontally and five feet vertically.

Space 10x12 wales at five feet vertically.

Space 2x6 uprights at two feet vertically.

(3) *Example 3.*

A trench dug in Type C soil is 13 feet deep and five feet wide.

From *Table C-1.3* two acceptable arrangements of members can be used.

Arrangement #1

Space 8x8 crossbraces at six feet horizontally and five feet vertically.

Space 10x12 wales at five feet vertically.

Position 2x6 uprights as closely together as possible.

If water must be retained use special tongue and groove uprights to form tight sheeting.

Arrangement #2

Space 8x10 crossbraces at eight feet horizontally and five feet vertically.

Space 12x12 wales at five feet vertically.

Position 2x6 uprights in a close sheeting configuration unless water pressure must be resisted. Tight sheeting must be used where water must be retained.

(4) *Example 4.*

A trench dug in Type C soil is 20 feet deep and 11 feet wide. The size and spacing of members for the section of trench that is over 15 feet in depth is determined using Table C-1.3. Only one arrangement of members is provided.

Space 8x10 crossbraces at six feet horizontally and five feet vertically.

Space 12x12 wales at five feet vertically.

Use 3x6 tight sheeting.

Use of Tables C-2.1 through C-2.3 would follow the same procedures.

(g) *Notes for all Tables.*

1. Member sizes at spacings other than indicated are to be determined as specified in § 1926.652 (c), "Design of Protective Systems."

2. When conditions are saturated or submerged use Tight Sheeting. Tight Sheeting refers to the use of specially-edged timber planks (e.g., tongue and groove) at least three inches thick, steel sheet piling, or similar construction that when driven or placed in position provide a tight wall to resist the lateral pressure of water and to prevent the loss of backfill material. Close Sheeting refers to the placement of planks side-by-side allowing as little space as possible between them.

3. All spacing indicated is measured center to center.

4. Wales to be installed with greater dimension horizontal.

5. If the vertical distance from the center of the lowest crossbrace to the bottom of the trench exceeds two and one-half feet, uprights shall be firmly embedded or a mudsill shall be used. Where uprights are embedded, the vertical distance from the center of the lowest crossbrace to the bottom of the trench shall not exceed 36 inches. When mudsills are used, the vertical distance shall not exceed 42 inches. Mudsills are wales that are installed at the toe of the trench side.

6. Trench jacks may be used in lieu of or in combination with timber crossbraces.

7. Placement of crossbraces. When the vertical spacing of crossbraces is four feet, place the top crossbrace no more than two feet below the top of the trench. When the vertical spacing of crossbraces is five feet, place the top crossbrace no more than 2.5 feet below the top of the trench.

TABLE C-1.1
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A $P_a = 25 \times H + 72$ psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (ACTUAL) AND SPACING OF MEMBERS **												
	Horiz. Spacing (feet)	CROSS BRACES						WALES		UPRIGHTS			
		Width of Trench (feet)					Vert. Spacing (feet)	Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet)			
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close	4	5	6	8
5 To 10	Up to 6	4x4	4x4	4x6	6x6	6x6	4	Not Req'd	- - -				2x6	
	Up to 8	4x4	4x4	4x6	6x6	6x6	4	Not Req'd	- - -					2x8
	Up to 10	4x6	4x6	4x6	6x6	6x6	4	8x8	4			2x6		
	Up to 12	4x6	4x6	6x6	6x6	6x6	4	8x8	4				2x6	
10 To 15	Up to 6	4x4	4x4	4x6	6x6	6x6	4	Not Req'd	- - -				3x8	
	Up to 8	4x6	4x6	6x6	6x6	6x6	4	8x8	4		2x6			
	Up to 10	6x6	6x5	6x6	6x8	6x8	4	8x10	4			2x6		
	Up to 12	6x6	6x6	6x6	6x8	6x8	4	10x10	4				3x8	
15 To 20	Up to 6	6x6	6x6	6x6	6x8	6x8	4	6x8	4	3x6				
	Up to 8	6x6	6x6	6x6	6x8	6x8	4	8x8	4	3x6				
	Up to 10	8x8	8x8	8x8	8x8	8x10	4	8x10	4	3x6				
	Up to 12	8x8	8x8	8x8	8x8	8x10	4	10x10	4	3x6				
Over 20	See Note 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-1.2
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (ACTUAL) AND SPACING OF MEMBERS **												
	Horiz. Spacing (feet)	CROSS BRACES					Vert. Spacing (feet)	WALES		UPRIGHTS			
		Width of Trench (feet)						Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet)			
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close	2	3	
5 To 10	Up to 6	4x6	4x6	6x6	6x6	6x6	5	6x8	5			2x6	
	Up to 8	6x6	6x6	6x6	6x8	6x8	5	8x10	5			2x6	
	Up to 10	6x6	6x6	6x6	6x8	6x8	5	10x10	5			2x6	
	See Note 1												
10 To 15	Up to 6	6x6	6x6	6x6	6x8	6x8	5	8x8	5		2x6		
	Up to 8	6x8	6x8	6x8	8x8	8x8	5	10x10	5		2x6		
	Up to 10	8x8	8x8	8x8	8x8	8x10	5	10x12	5		2x6		
	See Note 1												
15 To 20	Up to 6	6x8	6x8	6x8	8x8	8x8	5	8x10	5	3x6			
	Up to 8	8x8	8x8	8x8	8x8	8x10	5	10x12	5	3x6			
	Up to 10	8x10	8x10	8x10	8x10	10x10	5	12x12	5	3x6			
	See Note 1												
Over 20	See Note 1												

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-1.3
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C P_a = 80 X H + 72 psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (ACTUAL) AND SPACING OF MEMBERS **													
	Horiz. Spacing (feet)	CROSS BRACES						WALES		UPRIGHTS				
		Width of Trench (feet)					Vert. Spacing (feet)	Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet) (See Note 2)				
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close				
5 To 10	Up to 6	6x8	6x8	6x8	8x8	8x8	5	8x10	5	2x6				
	Up to 8	8x8	8x8	8x8	8x8	8x10	5	10x12	5	2x6				
	Up to 10	8x10	8x10	8x10	8x10	10x10	5	12x12	5	2x6				
	See Note 1													
10 To 15	Up to 6	8x8	8x8	8x8	8x8	8x10	5	10x12	5	2x6				
	Up to 8	8x10	8x10	8x10	8x10	10x10	5	12x12	5	2x6				
	See Note 1													
	See Note 1													
15 To 20	Up to 6	8x10	8x10	8x10	8x10	10x10	5	12x12	5	3x6				
	See Note 1													
	See Note 1													
	See Note 1													
Over 20	See Note 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.1
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A $P_a = 25 \times H + 72$ psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (S4S) AND SPACING OF MEMBERS **													
	Horiz. Spacing (feet)	CROSS BRACES					Vert. Spacing (feet)	WALES		UPRIGHTS				
		Width of Trench (feet)						Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet)				
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close	4	5	6	8
5 To 10	Up to 6	4x4	4x4	4x4	4x4	4x6	4	Not Req'd	Not Req'd				4x6	
	Up to 8	4x4	4x4	4x4	4x6	4x6	4	Not Req'd	Not Req'd					4x8
	Up to 10	4x6	4x6	4x6	6x6	6x6	4	8x8	4			4x6		
	Up to 12	4x6	4x6	4x6	6x6	6x6	4	8x8	4				4x6	
10 To 15	Up to 6	4x4	4x4	4x4	6x6	6x6	4	Not Req'd	Not Req'd				4x10	
	Up to 8	4x6	4x6	4x6	6x6	6x6	4	6x8	4		4x6			
	Up to 10	6x6	6x6	6x6	6x6	6x6	4	8x8	4			4x8		
	Up to 12	6x6	6x6	6x6	6x6	6x6	4	8x10	4		4x6		4x10	
15 To 20	Up to 6	6x6	6x6	6x6	6x6	6x6	4	6x8	4	3x6				
	Up to 8	6x6	6x6	6x6	6x6	6x6	4	8x8	4	3x6	4x12			
	Up to 10	6x6	6x6	6x6	6x6	6x8	4	8x10	4	3x6				
	Up to 12	6x6	6x6	6x6	6x8	6x8	4	8x12	4	3x6	4x12			
Over 20	See Note 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may be substituted for wood.

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TABLE C-2.2
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (S4S) AND SPACING OF MEMBERS **													
	Horiz. Spacing (feet)	CROSS BRACES						WALES		UPRIGHTS				
		Width of Trench (feet)					Vert. Spacing (feet)	Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet)				
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close	2	3	4	6
5 To 10	Up to 6	4x6	4x6	4x6	6x6	6x6	5	6x8	5			3x12 4x8		4x12
	Up to 8	4x6	4x6	6x6	6x6	6x6	5	8x8	5		3x8		4x8	
	Up to 10	4x6	4x6	6x6	6x6	6x8	5	8x10	5			4x8		
	See Note 1													
10 To 15	Up to 6	6x6	6x6	6x6	6x8	6x8	5	8x8	5	3x6	4x10			
	Up to 8	6x8	6x8	6x8	8x8	8x8	5	10x10	5	3x6	4x10			
	Up to 10	6x8	6x8	8x8	8x8	8x8	5	10x12	5	3x6	4x10			
	See Note 1													
15 To 20	Up to 6	6x8	6x8	6x8	6x8	8x8	5	8x10	5	4x6				
	Up to 8	6x8	6x8	6x8	8x8	8x8	5	10x12	5	4x6				
	Up to 10	8x8	8x8	8x8	8x8	8x8	5	12x12	5	4x6				
	See Note 1													
Over 20	See Note 1													

* Douglas Fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.3
TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C $P_a = 80 \times H + 72$ psf (2 ft Surcharge)

Depth of Trench (feet)	SIZE (ACTUAL) AND SPACING OF MEMBERS **														
	Horiz. Spacing (feet)	CROSS BRACES					Vert. Spacing (feet)	WALES		UPRIGHTS				
		Width of Trench (feet)						Size (in)	Vert. Spacing (feet)	Maximum Allowable Horizontal Spacing (feet)				
		Up to 4	Up to 6	Up to 9	Up to 12	Up to 15				Close				
5 To 10	Up to 6	6x6	6x6	6x6	6x6	8x8	5	8x8	5	3x6				
	Up to 8	6x6	6x6	6x6	8x8	8x8	5	10x10	5	3x6				
	Up to 10	6x6	6x6	8x8	8x8	8x8	5	10x12	5	3x6				
	See Note 1													
10 To 15	Up to 6	6x8	6x8	6x8	8x8	8x8	5	10x10	5	4x6				
	Up to 8	8x8	8x8	8x8	8x8	8x8	5	12x12	5	4x6				
	See Note 1													
	See Note 1													
15 To 20	Up to 6	8x8	8x8	8x8	8x10	8x10	5	10x12	5	4x6				
	See Note 1													
	See Note 1													
	See Note 1													
Over 20	See Note 1													

* Douglas Fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

Appendix D to Subpart P

Aluminum Hydraulic Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used when aluminum hydraulic shoring is provided as a method of protection against cave-ins in trenches that do not exceed 20 feet (6.1 m) in depth. This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with § 1926.652 (c)(2).

(b) *Soil Classification.* In order to use data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of part 1926.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables D-1.1, D-1.2, D-1.3, and E-1.4. Each table presents the maximum vertical and horizontal spacings that may be used with various aluminum member sizes and various hydraulic cylinder sizes. Each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. Tables D-1.1, and D-1.2 are for vertical shores in Types A and B soil. Tables D-1.3 and D-1.4 are for horizontal waler systems in Types B and C soil.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations (footnotes) regarding Table D-1.1 through D-1.4 are presented in paragraph (g) of this appendix.

(6) Figures, illustrating typical installations of hydraulic shoring, are included just prior to the Tables. The illustrations page is entitled "Aluminum Hydraulic Shoring: Typical Installations."

(d) *Basis and limitations of the data.*

(1) Vertical shore rails and horizontal wales are those that meet the Section Modulus requirements in the D-1 Tables. Aluminum material is 6061-T6 or material of equivalent strength and properties.

(2) Hydraulic cylinders specifications. (i) 2-inch cylinders shall be a minimum 2-inch inside diameter with a minimum safe working capacity of no less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe working capacity of not less than 30,000 pounds axial compressive load at extensions as recommended by product manufacturer.

(3) Limitation of application.

(i) It is not intended that the aluminum hydraulic specification apply to every situation that may be experienced in the field. This data was developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix

must be otherwise designed as specified in § 1926.652 (c).

(ii) When any of the following conditions are present, the members specified in the Tables are not considered adequate. In this case, an alternative aluminum hydraulic shoring system or other type of protective system must be designed in accordance with § 1926.652.

(A) When vertical loads imposed on cross braces exceed a 100 pound gravity load distributed on a one-foot section of the center of the hydraulic cylinder.

(B) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(C) When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables D-1.1, D-1.2, D-1.3, and D-1.4.* The members of the shoring system that are to be selected using this information are the hydraulic cylinders, and either the vertical shores or the horizontal wales. When a waler system is used the vertical timber sheeting to be used is also selected from these tables. The Tables D-1.1 and D-1.2 for vertical shores are used in Type A and B soils that do not require sheeting. Type B soils that may require sheeting, and Type C soils that always require sheeting are found in the horizontal wale Tables D-1.3 and D-1.4. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is made. The selection is based on the depth and width of the trench where the members are to be installed. In these tables the vertical spacing is held constant at four feet on center. The tables show the maximum horizontal spacing of cylinders allowed for each size of wale in the waler system tables, and in the vertical shore tables, the hydraulic cylinder horizontal spacing is the same as the vertical shore spacing.

(f) *Example to Illustrate the Use of the Tables:*

(1) *Example 1:*

A trench dug in Type A soil is 6 feet deep and 3 feet wide. From Table D-1.1: Find vertical shores and 2 inch diameter cylinders spaced 8 feet on center (o.c.) horizontally and 4 feet on center (o.c.) vertically. (See Figures 1 and 3 for typical installations.)

(2) *Example 2:*

A trench is dug in Type B soil that does not require sheeting, 13 feet deep and 5 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinders spaced 6.5 feet o.c. horizontally and 4 feet o.c. vertically. (See Figures 1 and 3 for typical installations.)

(3) *Example 3:*

A trench is dug in Type B soil that does not require sheeting, but does experience some minor raveling of the trench face. The trench is 16 feet deep and 9 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinder (with special oversleeves as designated by footnote #2) spaced 5.5 feet o.c. horizontally and 4 feet o.c. vertically, plywood (per footnote (g)(7) to the D-1 Table) should be used behind the shores. (See Figures 2 and 3 for typical installations.)

(4) *Example 4*: A trench is dug in previously disturbed Type B soil, with characteristics of a Type C soil, and will require sheeting. The trench is 18 feet deep and 12 feet wide. 8 foot horizontal spacing between cylinders is desired for working space. From Table D-1.3: Find horizontal wale with a section modulus of 14.0 spaced at 4 feet o.c. vertically and 3 inch diameter cylinder spaced at 9 feet maximum o.c. horizontally. 3X12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(5) *Example 5*: A trench is dug in Type C soil, 9 feet deep and 4 feet wide. Horizontal cylinder spacing in excess of 6 feet is desired for working space. From Table D-1.4: Find horizontal wale with a section modulus of 7.0 and 2 inch diameter cylinders spaced at 6.5 feet o.c. horizontally. Or, find horizontal wale with a 14.0 section modulus and 3 inch diameter cylinder spaced at 10 feet o.c. horizontally. Both wales are spaced 4 feet o.c. vertically. 3x12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(g) *Footnotes, and general notes, for Tables D-1.1, D-1.2, D-1.3, and D-1.4.*

(1) For applications other than those listed in the tables, refer to § 1926.652 (c)(2) for use of manufacturer's tabulated data. For trench depths in excess of 20 feet, refer to § 1926.652 (c)(2) and § 1926.652 (c)(3).

(2) 2 inch diameter cylinders, at this width, shall have structural steel tube (3.5X3.5X0.1875) oversleeves, or structural oversleeves of manufacturer's specification, extending the full, collapsed length.

(3) Hydraulic cylinders capacities. (i) 2-inch cylinders shall be a minimum 2-inch inside diameter with a safe working capacity of not less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe work capacity of not less than 30,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(4) All spacing indicated is measured center to center.

(5) Vertical shoring rails shall have a minimum section modulus of 0.40 inch.

(6) When vertical shores are used, there must be a minimum of three shores spaced equally, horizontally, in a group.

(7) Plywood shall be 1.125 inches thick softwood or 0.75 inches thick, 14 ply, arctic white birch (Finland form). Please note that plywood is not intended as a structural member, but only for prevention of local raveling (sloughing of the trench face) between shores.

(8) See appendix C for timber specifications.

(9) Wales are calculated for simple span conditions.

(10) See appendix D, item (d), for basis and limitations of the data.

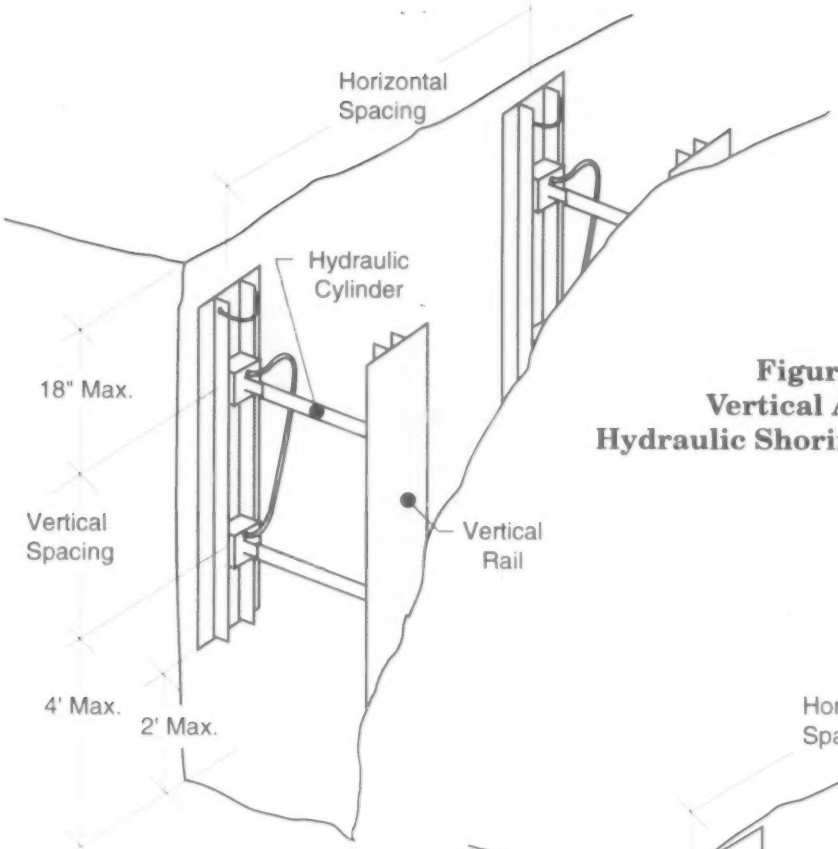

Figure No. 1
Vertical Aluminum
Hydraulic Shoring (Spot Bracing)

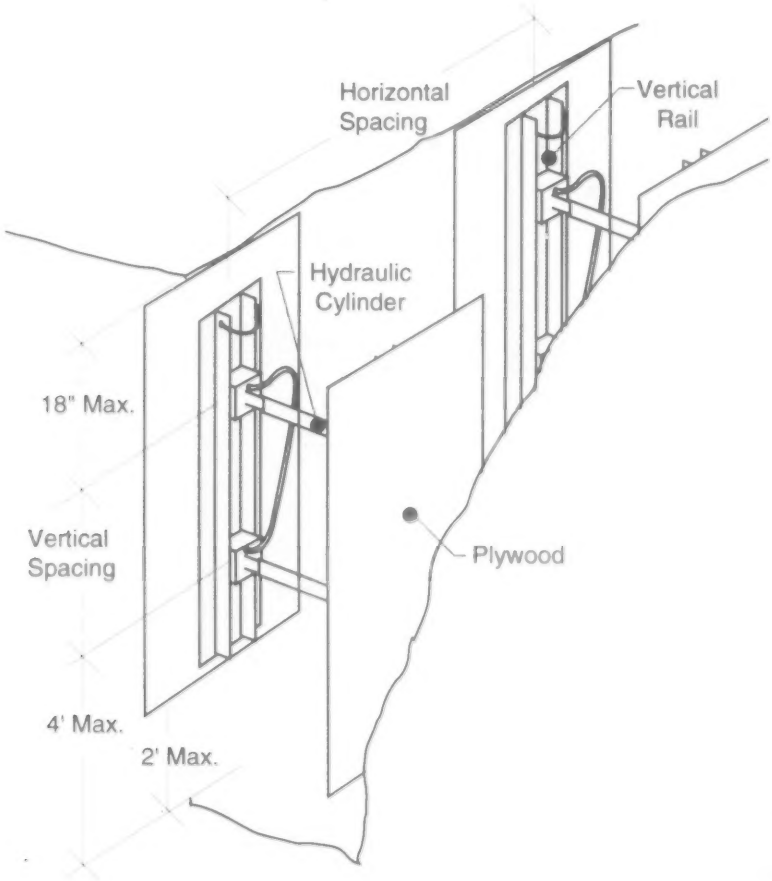

Figure No. 2
Vertical Aluminum
Hydraulic Shoring (With Plywood)

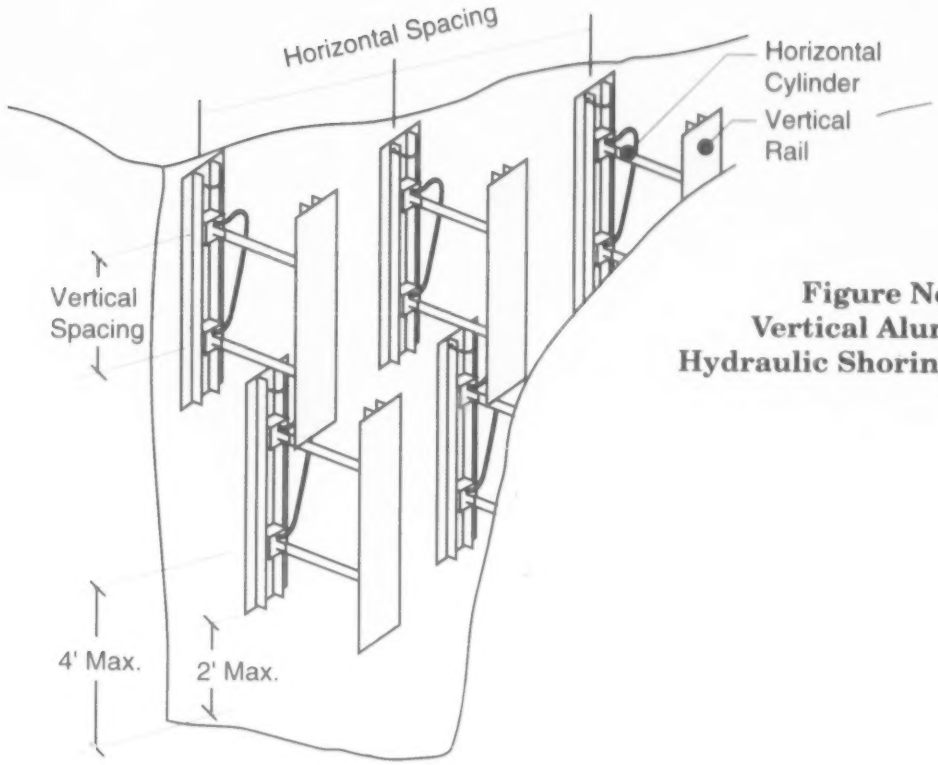

Figure No. 3
Vertical Aluminum Hydraulic Shoring (Stacked)

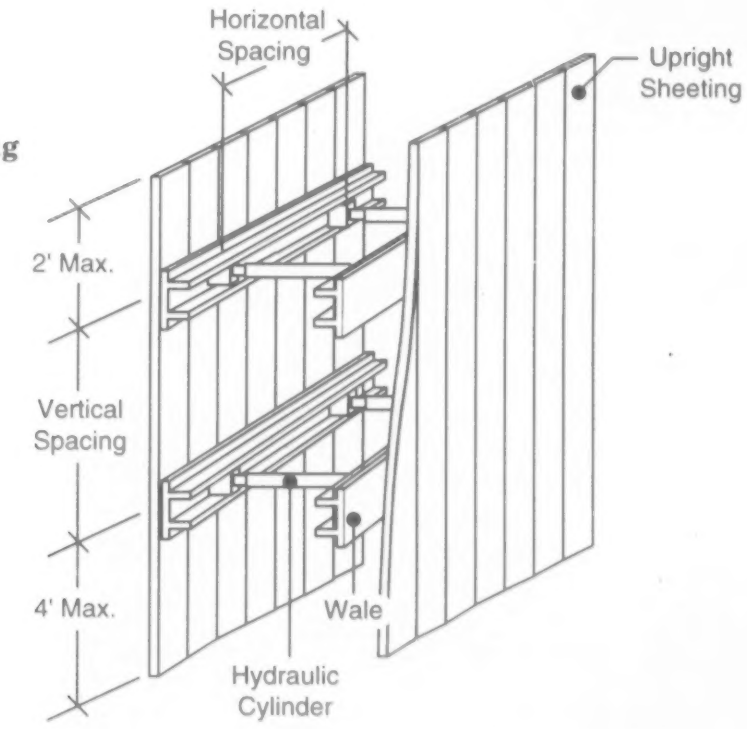

Figure No. 4
Aluminum Hydraulic Shoring Waler System (Typical)

TABLE D-1.1
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE A

Depth of Trench (feet)	Hydraulic Cylinders				
	Maximum Horizontal Spacing (feet)	Maximum Vertical Spacing (feet)	Width Of Trench (feet)		
			Up to 8	Over 8 Up to 12	Over 12 Up to 15
Over 5 Up to 10	8	4	2 Inch Diameter	2 Inch Diameter Note (2)	3 Inch Diameter
Over 10 Up to 15	8				
Over 15 Up to 20	7				
Over 20	Note (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)

TABLE D-1.2
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE B

Depth of Trench (feet)	Hydraulic Cylinders				
	Maximum Horizontal Spacing (feet)	Maximum Vertical Spacing (feet)	Width Of Trench (feet)		
			Up to 8	Over 8 Up to 12	Over 12 Up to 15
Over 5 Up to 10	8	4	2 Inch Diameter	2 Inch Diameter Note (2)	3 Inch Diameter
Over 10 Up to 15	6.5				
Over 15 Up to 20	5.5				
Over 20	Note (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)

TABLE D-1.3
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE B

Depth of Trench (feet)	Wales		Hydraulic Cylinders						Timber Uprights		
			Width Of Trench (feet)						Max. Horiz. Spacing (On Center)		
			Up to 8		Over 8 Up to 12		Over 12 Up to 15				
	Vertical Spacing (feet)	Section * Modulus (in^3)	Horiz. Spacing	Cylinder Diameter	Horiz. Spacing	Cylinder Diameter	Horiz. Spacing	Cylinder Diameter	Solid Sheet	2 Ft.	3 Ft.
Over 5 Up to 10	4	3.5	8.0	2 in	8.0	2 in Note (2)	8.0	3 in			3x12
		7.0	9.0	2 in	9.0	2 in Note (2)	9.0	3 in			
		14.0	12.0	3 in	12.0	3 in	12.0	3 in			
Over 10 Up to 15	4	3.5	6.0	2 in	6.0	2 in Note (2)	6.0	3 in		3x12	
		7.0	8.0	3 in	8.0	3 in	8.0	3 in			
		14.0	10.0	3 in	10.0	3 in	10.0	3 in			
Over 15 Up to 20	4	3.5	5.5	2 in	5.5	2 in Note (2)	5.5	3 in	3x12		
		7.0	6.0	3 in	6.0	3 in	6.0	3 in			
		14.0	9.0	3 in	9.0	3 in	9.0	3 in			
Over 20	Note (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g).
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

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TABLE D-1.4
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE C

Depth of Trench (feet)	Wales		Hydraulic Cylinders						Timber Uprights		
			Width Of Trench (feet)						Max. Horiz. Spacing (On Center)		
			Up to 8		Over 8 Up to 12		Over 12 Up to 15				
	Vertical Spacing (feet)	Section * Modulus (in^3)	Horiz. Spacing	Cylinder Diameter	Horiz. Spacing	Cylinder Diameter	Horiz. Spacing	Cylinder Diameter	Solid Sheet	2 Ft.	3 Ft.
Over 5 Up to 10	4	3.5	6.0	2 in	6.0	2 in Note (2)	6.0	3 in	3x12		
		7.0	6.5	2 in	6.5	2 in Note (2)	6.5	3 in			
		14.0	10.0	3 in	10.0	3 in	10.0	3 in			
Over 10 Up to 15	4	3.5	4.0	2 in	4.0	2 in Note (2)	4.0	3 in	3x12		
		7.0	5.5	3 in	5.5	3 in	5.5	3 in			
		14.0	8.0	3 in	8.0	3 in	8.0	3 in			
Over 15 Up to 20	4	3.5	3.5	2 in	3.5	2 in Note (2)	3.5	3 in	3x12		
		7.0	5.0	3 in	5.0	3 in	5.0	3 in			
		14.0	6.0	3 in	6.0	3 in	6.0	3 in			
Over 20	Note (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g).
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

APPENDIX E TO SUBPART P-
ALTERNATIVES TO TIMBER SHORING

Figure 1:
Aluminum Hydraulic Shoring

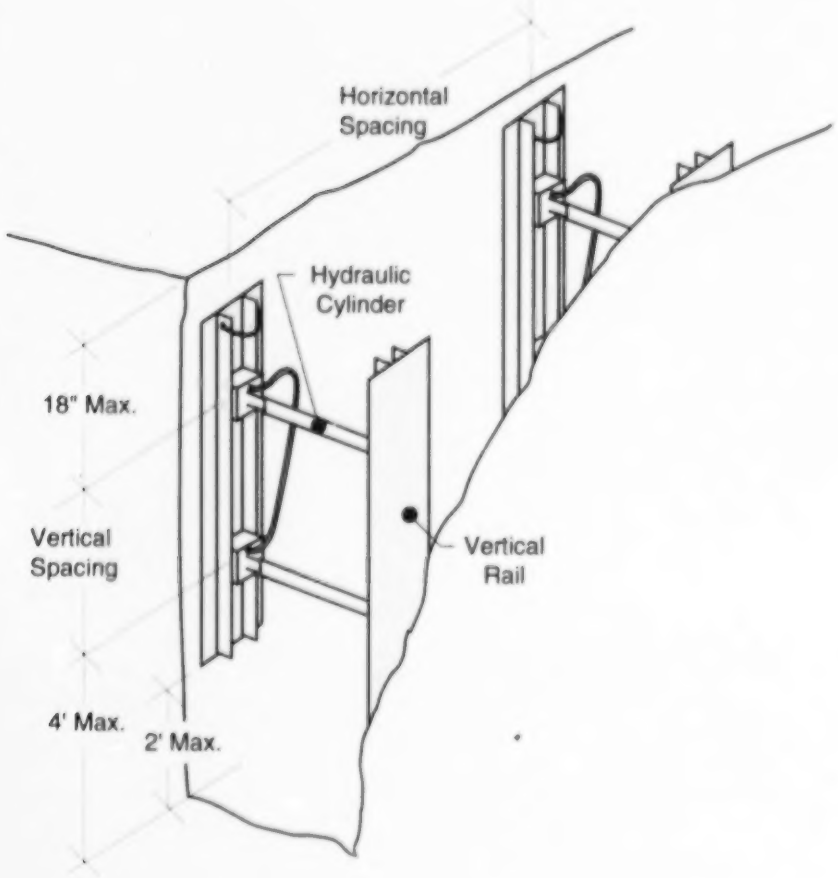


Figure 2:
Pneumatic/Hydraulic Shoring

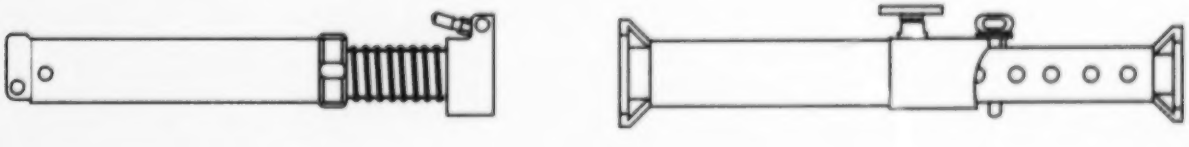


Figure 3
Trench Jacks (Screw Jacks)

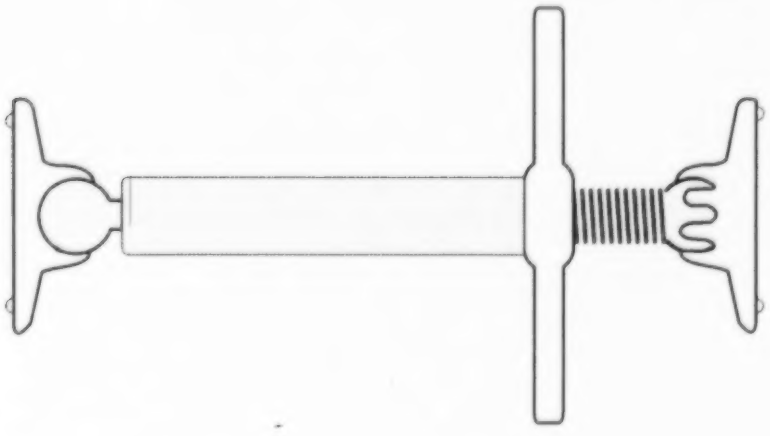
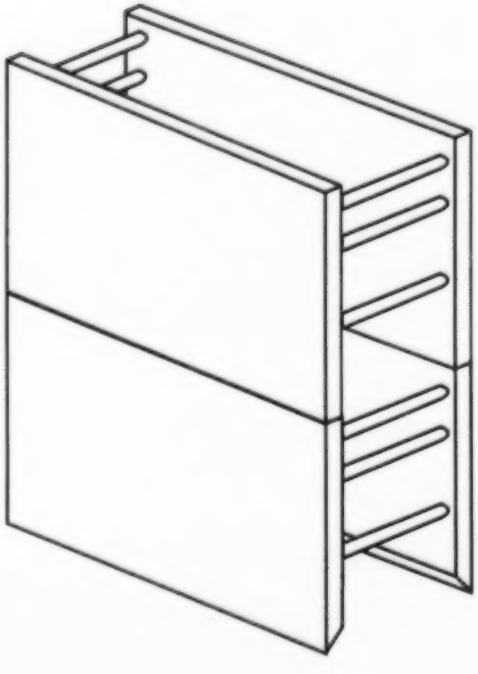


Figure 4
Trench Shield



APPENDIX F TO SUBPART S
SELECTION OF PROTECTIVE SYSTEMS

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet must be designed by a registered professional engineer in accordance with §1926.652(b) and (c).

Figure 1. Preliminary Decisions

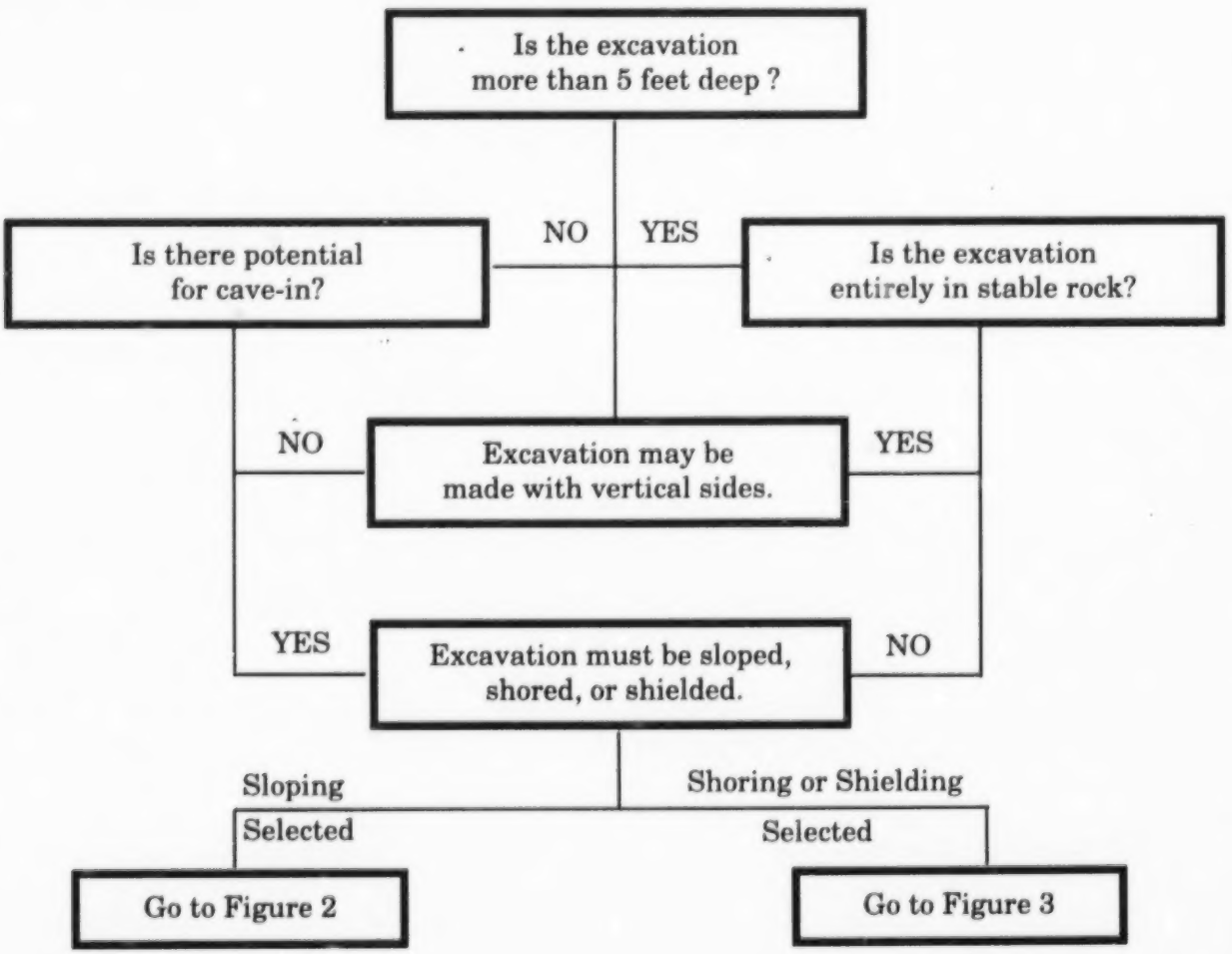


Figure 2. Sloping Options

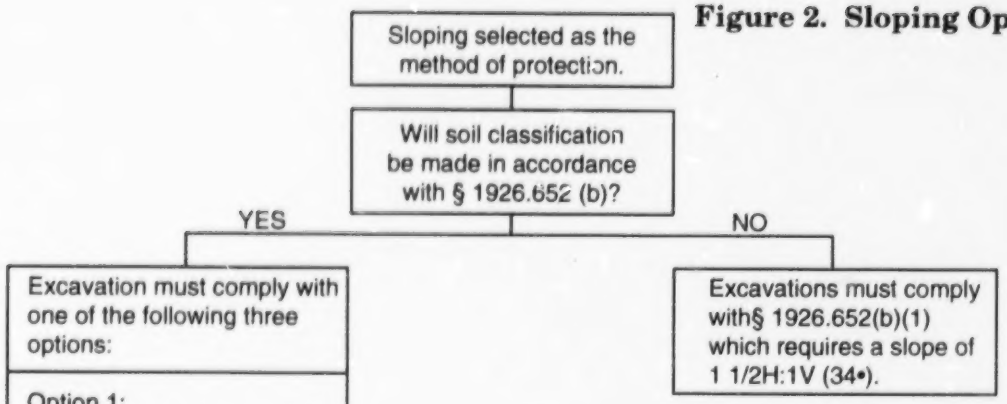
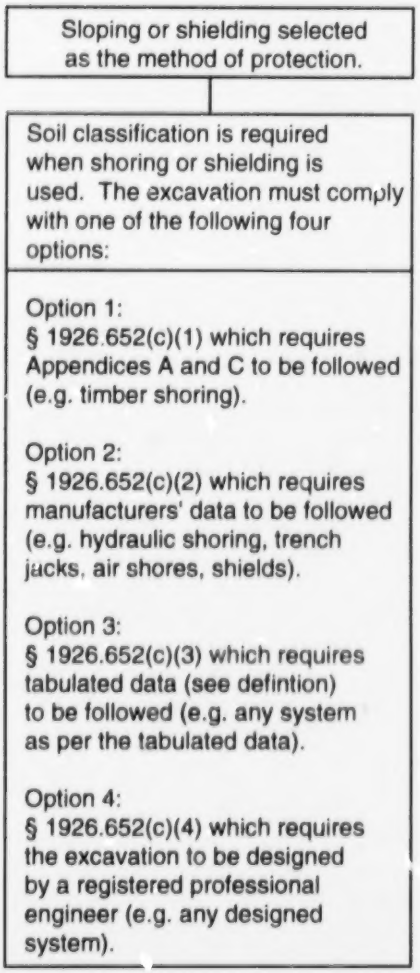

Sloping selected as the method of protection.
Will soil classification be made in accordance with § 1926.652 (b)?
YES
NO
Excavation must comply with one of the following three options:
Option 1:
§ 1926.652(b)(2) which requires Appendices A and B to be followed.
Option 2:
§ 1926.652(b)(3) which requires other tabulated data (see defintion) to be followed.
Option 3:
§ 1926.652(b)(4) which requires the excavation to be designed by a registered professional engineer.
Excavations must comply with§ 1926.652(b)(1) which requires a slope of 1 1/2H:1V (34•).

Figure 3. Shoring and Shielding Options


Sloping or shielding selected as the method of protection.
Soil classification is required when shoring or shielding is used. The excavation must comply with one of the following four options:
Option 1:
§ 1926.652(c)(1) which requires Appendices A and C to be followed (e.g. timber shoring).
Option 2:
§ 1926.652(c)(2) which requires manufacturers' data to be followed (e.g. hydraulic shoring, trench jacks, air shores, shields).
Option 3:
§ 1926.652(c)(3) which requires tabulated data (see defintion) to be followed (e.g. any system as per the tabulated data).
Option 4:
§ 1926.652(c)(4) which requires the excavation to be designed by a registered professional engineer (e.g. any designed system).

Appendix C

NIOSH-DIVISION OF SAFETY RESEARCH

Fatal Accident Circumstances & Epidemiology

FACE # 87-67-11

EST COPY AVAILABLE

NIOSH-DIVISION OF SAFETY RESEARCH
FACE-87-67-II
DATE: April 5, 1988

TO: Director, National Institute for Occupational Safety and Health

FROM: Division of Safety Research, NIOSH

SUBJECT: Two Construction Workers Die Inside Sewer Manhole in Indiana

Introduction:

The National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research (DSR) is currently conducting the Fatal Accident Circumstances of Epidemiology (FACE) Project, which is focusing on selected work-related fatalities.

On July 21, 1987, a worker for a construction company entered a seven foot deep sewer manhole that had a toxic and oxygen deficient atmosphere. When the worker collapsed, another worker entered the manhole in a rescue attempt and also collapsed. Both workers were pronounced dead at the scene.

Contacts/Activities:

Officials of the Occupational Safety and Health Administration for the State of Indiana notified DSR concerning the fatalities and requested technical assistance. This case has been included in the FACE Project. On September 16, 1987, a DSR research team (a research industrial hygienist and a safety specialist) met with the company owner, interviewed workers, and visited and photographed the accident site.

Overview of Employer's Safety Program:

The employer in this incident is a family owned construction company with approximately 50 workers (mostly laborers and heavy equipment operators). The majority of the company business involves general excavation and the construction of water systems, sewers, and roads. The company has a written, one-page safety policy which addresses employee responsibility, general safety guidelines, confined space safety, and reporting injuries.

It is the responsibility of each employee to read this policy. All management level employees are trained in cardiopulmonary resuscitation (CPR). Other than the CPR training, there is no formal classroom safety instruction for employees. Tool box meetings are held monthly to discuss basic safety issues. On-the-job safety is the responsibility of each employee.

No training is given on confined space entry; however, company policy requires that each manhole be tested and ventilated prior to entry. The company has gas monitoring devices available at the main office to test confined spaces for oxygen (O2), hydrogen sulfide (H2S), and methane (CH4). It should be noted that the company also experienced a confined space fatality five years prior to this incident.

Synopsis of Events:

On July 21, 1987, at approximately 11:00 a.m. a company work crew (a 36 year-old foreman with 17 years experience with the company, a 50 year-old heavy equipment operator with 21 years experience with the company, and two laborers) began clearing brush in a vacant field in preparation for setting grade stakes to extend an existing sewer line for a new housing subdivision. At 11:30 a.m. when the two laborers broke for lunch, the foreman and equipment operator both left to look for an existing sewer manhole.

Although there were no eye-witnesses to the incident, it is presumed (based on circumstantial evidence) that the following occurred: The foreman and equipment operator, upon locating the sewer manhole, removed the manhole cover. In an effort to check the existing sewer grade, the foreman then entered the seven-foot deep manhole through a 24-inch diameter "manway" opening, and collapsed at the bottom. In an attempt to rescue the downed foreman, the equipment operator entered the manhole and also collapsed.

After lunch, when the foreman and equipment operator did not return to the field that was being cleared, the two laborers began to search for them. At approximately 1:30 p.m. the two laborers found the foreman and equipment operator at the bottom of the manhole with their heads submerged in about 12 inches of water. One of the laborers told two other company workers (who had just arrived at the scene) to call for an ambulance. When the rescue squad from the local fire department arrived (after approximately 15 minutes), two fire department rescuers donned self-contained breathing apparatus (SCBA's), entered the manhole and, using ropes and harnesses, removed the two victims from the manhole.

Fire department and emergency medical service (EMS) personnel noted that the two victims were "obviously dead", and they were pronounced dead at the scene by the county coroner. After the victims were removed from the manhole, the atmosphere of the manhole was tested by a private analytical laboratory and by the City Water Pollution Control Maintenance Department. Results of these tests are as follows:

O2 at depth of 3 feet	15.7%
02 at depth of 6 feet	7.2%
CH4 at depth of 6 feet	.2%
H2S at depth of 6 feet	0.1% and 0.2%
CO at depth of 6 feet	>5%

Investigator's Comment:

The foreman and equipment operator were both employed by the company five years previous to this incident when the company experienced its first confined space fatality.

Cause of Death:

Autopsies were performed on both victims. The cause of death for both men was listed as asphyxiation.

Recommendations/Discussion

Recommendation #1: Employers engaged in the business of sewer construction or maintenance should assure that workers are trained sufficiently in recognition and awareness of confined space hazards they may encounter in the daily performance of their duties.

Discussion: According to the employer, the work being performed at the construction site did not require the workers to enter any sewer manhole. However, the foreman did enter the manhole without testing and ventilating the atmosphere of the manhole prior to entry as required by company safety policy. The fact that this is the second confined space fatality incident within the last five years (resulting in three confined space fatalities) underscores the importance of employee training in safe confined space work practices.

Recommendation #2: The employer should develop and implement a more comprehensive safety policy with specific procedures for confined space entry.

Discussion: The one page safety policy devotes one paragraph to confined space entry: "Employees shall not enter manholes, underground vaults, chambers, tanks, silos, or other similar places that receive little ventilation, unless it has been determined that the air contains no flammable or toxic gases or vapors. Ventilate thoroughly, detectors are available at office."

Phrases such as ". . . unless it has been determined . . . " and "ventilate thoroughly . . . " should be expanded and clarified to describe a detailed confined space entry procedure. Also, the individual(s) responsible for testing the atmosphere and making recommendations for safe entry should be identified. Minimally, the following confined

space safe work practices should be addressed in the company safety policy and implemented on the job:

1. Is confined space entry necessary? Can the task be completed from the outside?

2. Has a company safe entry permit been issued?

3. If entry is to be made, has the air quality in the confined space been tested?

   - Oxygen supply at least 19.5%
   - Flammable range less than 10% of the lower flammable limit
   - Absence of toxic air contaminants

4. Have employees and supervisors been trained in selection and use of personal protective equipment and clothing?

   - Protective clothing
   - Respiratory protection
   - Hard hats
   - Eye protection
   - Gloves
   - Life lines
   - Emergency rescue equipment

5. Have employees been trained for confined space entry?

6. Have employees been trained in confined space rescue procedures?

7. If ventilation equipment is needed, is it available and/or used?

8. Is the air quality tested when the ventilation system is operating?

The two fatalities would have been prevented if these recommendations had been followed. Specific recommendations regarding safe work practices in confined spaces can be found in NIOSH publications 80-106, "Working In Confined Spaces", and 87-113, "A Guide to Safety in Confined Spaces".

Additional information regarding this report is available from:

Division of Safety Research
National Institute for Occupational
Safety and Health (NIOSH)
944 Chestnut Ridge Road
Morgantown, West Virginia 26505-2888

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